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THE

MUSCLES OF THE EYE

BY

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FORMER CHAIRMAN, SEC. OPHTHALMOLOGY, AMERICAN MEDICAL ASSOCIATION

IN TWO VOLUMES

VOLUME II.

PATHOLOGY AND TREATMENT

ILLUSTRATED

G. P. PUTNAM'S SONS
NEW YORK AND LONDON
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1908

PREFACE.

In the preface to the first volume it was stated in substance that the object of this study was to collect actual facts relating to the ocular muscles, arrange them in order, and state them in terms as clear and simple as possible. The favorable criticisms of that volume encourage the hope that the effort was not entirely fruitless.

But the questions now before us are more difficult. Here we have the same problems of anatomy and of physiology, but complicated by the presence of certain unknown and variable factors which we call disease. In order to solve these problems, the general knowledge of the anatomy and physiology of the muscles possessed by the average ophthalmologist is by no means sufficient.

For example, the diagnosis of the simple forms of imbalance is difficult or impossible without such a knowledge of accommodation, convergence, and torsion as can be gained by a patient study of each of these, not only alone, but when combined with each other to produce comfortable binocular vision at a near point. The ordinary text-book is far too elementary for that purpose. Or again, the technique of some forms of tenotomy or advancement appears meaningless to one who has not dissected these muscles, and examined their primary and secondary insertions.

Indeed, the more we learn of the importance of the muscles and their effects on the globe, or, perhaps, on other portions of the body, the more does their study seem to form quite as distinct a part of ophthalmology as ophthalmology itself forms a distinct part of surgery. That is in proportion as hasty conclusions are supplanted by painstaking inquiry. This volume, for example, does not aim to point out short cuts to diagnosis, for time and patience are always the price of scientific accuracy.

It is generally admitted that the data relating to this subject, especially those concerning heterophoria and so-called "strabismus," have been in a confused or almost chaotic mass. Therefore, an attempt has been made to arrange them in a manner which it is hoped will prove simple and natural. It is true the outline here followed presents evident difficulties, because of the lack at intervals of connecting data. Still, the plan adopted of considering first the simple and then the compound forms of heterophoria and heterotropia forms the most natural basis for the study.

An effort has also been made to add a few observations, descriptions of instruments, and methods of treatment which may prove of some little value. Among these may be mentioned: additional methods of diagnosis of excessive and of insufficient accommodation; differences between simple and compound heterophoria; a modified strabometer scale for the measurement of amblyopia; photograms of ocular paralyses; the photogram of the lateral movements in tabes and in nystagmus; a tendon tucker, a tenotomy hook, advancement forceps and a method of anchoring the stitches in advancement.

Thanks should be expressed to Dr. Howard F. Hansell of Philadelphia for criticising the portion relating to muscle imbalance, and to Dr. Claud Worth of London for doing the same with the part relating to heterotropia. Dr. Edward Jackson of Denver has again been kind enough to make suggestions on occasional points throughout this volume, as he did with the first. It should be repeated, however, that these distinguished colleagues are in no way responsible for the many faults which the book contains.

The study, from first to last, has proved of engrossing interest and pleasure. But it is disappointing to feel that so much still remains unknown concerning this important branch of ophthalmology. In spite of the years which have been given to these two volumes they contain only the imperfect outline of a work on the subject which still remains to be written.

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PATHOLOGY AND TREATMENT.

PART I.

OCULAR MUSCLE IMBALANCE.

CHAPTER I.

DEFINITIONS AND PRELIMINARY CONSIDERATIONS.

§ 1. **Balance of the Ocular Muscles, the Standard for Comparison.**—Our studies of the normal action of the muscles led by successive steps to the conclusion that there are three primary forces involved in the act of comfortable vision at the near point,—namely, accommodation, convergence, and torsion. We found each of these primary forces to be associated with a secondary one which might be called the "resistance" offered to that force. That is, we have three primary and three secondary forces, or at least six in all, entering into the act of vision with both eyes at a near point. Each of these forces has been called also a "factor" or "element." Balance of the ocular muscles has been described as the condition in which, with comfortable binocular vision, the accommodation, convergence, and torsion bear their normal relations to each other. Although this condition is as rare perhaps as is "perfect health" in the human body, still methods of examination now at our command show that this balance does exist.

We have also found that if we wish to obtain a clearer

mental picture of muscle balance we can illustrate it by a diagram. This is reproduced in Fig. 1, for the convenience

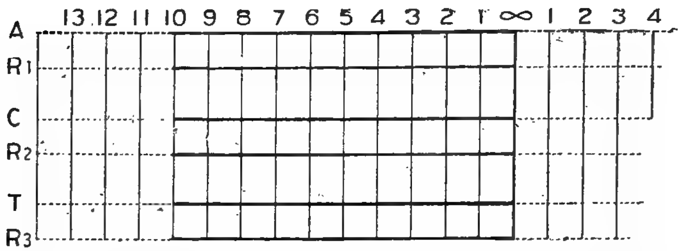

FIG. 1.—Diagrammatic illustration of muscle balance (Eukinesis). In this young person the accommodation, convergence, and torsion, with the resistance to each, is normal up to 10 D.

of those who have not read the first volume, and also because the ideal normal standard of muscle balance must be kept in mind in all studies of imbalance. In this figure the line A represents the range of accommodation in a person who can read the proper test letters with both eyes at a distance of six meters or more, and also up to a near point, normal for one of his age,—for example, at one tenth of a meter. R_1 represents the resistance which is offered to the ciliary muscle by the inelasticity of the lens and other causes which have been already described. The line C represents the convergence which is made by the individual as the axes change from parallelism until they converge at a point ten meter angles in front of the center of the base line. The line R_2 indicates the resistance offered by the external recti and otherwise to this degree of convergence. The line T represents the true torsion which accompanies this degree of accommodation and of convergence, while the line R_3 represents the resistance offered to this degree of torsion. In this person, as these three primary and three secondary factors in the production of normal vision bear their normal relations to each other, we have muscle balance or *eukinesis*.

But it should also be observed that when the normal relations between these factors are disturbed *beyond certain limits for that individual* there is discomfort, and that dis-

comfort continues until the proper relations are re-established. The range or variation in any one of these factors which is possible without a sensation of real discomfort has been called *the area of comfort.* In some individuals, especially those whose muscular system is well developed, this area of comfort is comparatively large. If such a person is slightly presbyopic or hypermetropic no glasses are required, or wrong ones elicit only slight complaints. But if this area of comfort is small, especially in a neurasthenic, the balance is so easily disturbed and so frequently changing as to make it difficult or impossible to establish the proper relations between accommodation and convergence or between either or both of these and torsion.

It should be repeated that the lack of familiarity with the underlying principles which were worked out in the first volume is one of the most fruitful causes of the confusion in our knowledge of the ocular muscles. The practitioner who imagines that even a large experience in the treatment of heterophoria or the performance of several hundred tenotomies will take the place of a broad and firm basis for his knowledge, is doomed to woeful disappointment. Many of the most valuable methods of diagnosis will not be appreciated by him, simply because they are not sufficiently understood.

§ 2. **Imbalance of the Ocular Muscles.**—Ocular muscle imbalance or muscle imbalance or simply imbalance has been described as the condition in which accommodation, convergence, and torsion *do not* bear their normal relations to each other. It might also be called *dyskinesis* in contradistinction to *eukinesis.* This definition is so broad that in a certain sense it might include almost everything abnormal about the ocular muscles. In order to obtain a clearer understanding of this let us glance for a moment at the evolution of our ideas concerning those abnormal conditions or functions of these ocular muscles which we may properly call their *anomalies.*

The earliest surgeons noticed only the most obvious deviations of the eyes from the positions which they should occupy. Centuries elapsed before a difference was recog-

nized between the paralyses and what was called "strabismus." About the middle of the last century it was found by von Graefe and others that even when the visual axes appeared to the casual observer to be in a normal position, suitable tests, such as have been described, sometimes showed a tendency to some deviation. This deviation was therefore called a *latent* convergence, divergence, etc. Or, according to a more modern nomenclature, these were forms of *heterophoria*. While the various anomalies of the extra-ocular muscles were carefully studied, especially in America, anomalies of accommodation also received some attention. The action of myotics and cycloplegics, and more extended clinical experience, showed that spasm and also paresis of the accommodation, in slight degrees, occurred more frequently than had been supposed. Thus gradually the term "ocular muscle imbalance" or "muscle imbalance" or simply "imbalance" came to be used, especially by American and English writers, to describe all "latent" abnormalities of the ocular muscles.

It is evident that ocular imbalance also occurs in heterotropia and in paralyses, but unless the contrary is specified we will understand in what follows that the term "imbalance" in its different forms refers only to *latent* deviations, and not to those which are *apparent*. Finally, it should be remembered that in all forms of eye-strain, the ultimate cause of uncomfortable symptoms is the instinctive effort to obtain and to maintain perfect vision, and also binocular vision, when that is possible.

§ 3. **Forms of Imbalance.**—Having defined imbalance, we next enquire as to its various forms. It is customary to speak of them as varieties of *asthenopia*. That term is unfortunate, because, as we shall see later, it has become so indefinite as to mean almost any condition or symptom. We cannot, however, strike it out at will, as words remain in spite of writers or lexicographers. Therefore it seems best to treat this word in medicine as similar words are treated in law,—retain it, but give it a limited and definite meaning. In order to see the need of doing this, and also to give an outline of the whole plan of study of this phase

of our subject, let us follow the example of Tyndall in physics or of James in psychology by using an illustration.

Suppose some farmer intending to build a house had received everything pertaining to it at once, and that the materials of all kinds had been piled in one heap upon his land. His first effort would be to separate them into three groups.

In the first, he would place all that related to the foundation—stone, bricks, mortar, etc.; in the second, he would pile the wood and what related to the superstructure; and in the third he would collect whatever pertained to furnishings or ornament. Each one of these groups would contain articles belonging together, though they would still be without any system or arrangement in themselves. His second step would be to classify the different articles in each of these three groups; he would place all the stone together, the bricks together, etc. In the next group he would place the beams, boards, and the shingles each by themselves, and so on until all the articles in each of the three groups which he made at first had also been classified. It is true, questions might arise as to just where certain bricks or pieces of wood belonged, but that would be a matter of detail, and finally the materials for his house would be sufficiently well classified for him to build a permanent and useful structure.

Something like that occurred about half a century ago in this department of our science. With that remarkable advance—that renaissance in ophthalmology—which took place about the middle of the last century, the pioneers in this study found suddenly placed before them a mass of data, physiological and clinical, relating to what had previously been called "asthenopia"—that is, symptoms which had been ascribed to the retina. These were divided into three general groups called respectively accommodative, muscular, and central asthenopia. Until recently it has been deemed quite sufficient to arrange the confused mass of data into three groups, which could be distinguished from each other. The task now before us is to subdivide these into still smaller groups, and to fit the different parts into each other as best we can, in workmanlike fashion.

In a word, we shall try to hold as closely as possible to the earlier classification of accommodative, muscular, and central asthenopia. But we shall dispense where we can with the term "asthenopia," and use others which are more exact. As far as central asthenopia is concerned, however, the little that we really know concerning it will form part of a chapter devoted to the reflexes to the eye from other parts of the body.

Apparently the data at our command are sufficient to warrant this attempt to determine more exactly the different forms of muscle imbalance. At this point we shall simply indicate what some of these forms are and glance at them when placed in tabular form. Later, each will be studied in detail.

In arranging the forms of muscle imbalance we naturally group together those which relate to the intraocular muscles, and those which relate to the extraocular muscles. But at the outset we are met by a lack in our nomenclature. We find that we have no one term which includes anomalies of accommodation, as heterophoria includes forms of imbalance of the extraocular muscles, or as ametropia includes anomalies of refraction. It is certain that our confusion of ideas concerning imbalance is due in part to the fact that anomalies of accommodation are often described as forms of heterophoria, though of course they are not. According to the more modern nomenclature, "orthophoria is a tendency of the visual lines to parallelism," and "heterophoria is a tendency of the lines in some other way." Evidently that has nothing to do with the ciliary muscle. It would be venturesome to attempt the introduction of any new term in spite of the evident need, were it not that we are familiar with combinations of *hetero* (varied), and *cyclo* (as in cyclitis) and also with another root word *kinesis*, meaning strength or tonicity. We could therefore use the term *heterocykinesis* when a single word is really desired, but we shall find it better, whenever possible, to use simple English terms and to refer to abnormal actions of the intraocular muscles as anomalies of accommodation.

In asking ourselves what these are we must keep the nor-

mal standard always in mind. Accommodation which is greater than normal we would naturally call *excessive accommodation* or *spasm of the accommodation ;* or, if it is preferred to use a classical term, *accommodative hyperkinesis.* Accommodation which is less than normal we would naturally call *insufficient* or *sub-normal accommodation*, or *paresis of the accommodation*, or *accommodative hypokinesis.*

Moreover, in a given case actual excess or spasm of the accommodation may not exist, but if the eye is myopic, a power of accommodation which is really only normal, may then be excessive *with relation to* the demand made upon it. So again, an actual insufficiency or paresis of accommodation may not exist, but if the eye is hypermetropic, a power of accommodation which is only normal, may be insufficient *with relation to* the demand made upon it.

With this brief reference to the forms of imbalance which are dependent upon abnormal action of the intraocular muscles, we can pass next to the forms of imbalance which are dependent upon abnormal action of the extraocular muscles. These have been studied apparently with more care than have anomalies of accommodation. We know these as latent deviations, or under the general term *heterophoria.* Moreover, as such deviations, at least in a slight degree, occur frequently in eyes which are otherwise practically normal, it was necessary, in our study of the physiology of the muscles, to consider heterophoria in its ordinary forms sufficiently to examine the tests for that condition and the methods of making the corresponding measurements. (Vol. I, p. 220.)

But the question now before us is, what is the *nature* of a given latent deviation ? In a case of esophoria, is that deviation inward due to excessive contraction of the adductors, is it a real spasm either primarily in the adductors or associated with excessive accommodation—that is, is it an *active esophoria*—an *actual excessive convergence?* Or is this tendency to deviation inward dependent on some abnormal relaxation of the abductors—that is, is it a *passive esophoria?* In that case it would be an esophoria only *in relation to* the comparative strength of the abductors, and may therefore,

be considered not as an actual but a *relative excessive convergence.* It is evident that in a similar manner *exophoria* may be either of an *active* or of *a relative,* that is, *a passive* character.

With this superficial glance at the various forms of muscle imbalance, we can make a tabular grouping of them as follows:

Forms of Muscle Imbalance	Heterocykinesis.	Actual excessive accommodation. (Spasm.)
		Relative excessive accommodation.
		Actual insufficient accommodation. (Paresis.)
		Relative insufficient accommodation. (Paresis.)
	Heterophorta.	Active esophoria. (Actual excessive conv.)
		Passive esophoria. (Relative excessive conv.)
		Active exophoria. (Relative insufficient conv.)
		Passive exophoria. (Actual insufficient conv.)
		Excessive torsion. (Excessive rotation out.)
		Insufficient torsion. (Insufficient rotation out.)
		Latent vertical deviations.

§4. **Simple and Compound Forms of Imbalance.**—*A simple form of imbalance* is one in which there is an abnormal condition of only one of the principal forces or pair of forces which enter into the act of normal binocular vision. In other words, it is some disturbance of accommodation only, or of convergence only, or of torsion only, either without or with a disturbance of the resistance normally offered to each of these principal forces. It is such a condition as we can produce at will in a pair of normally balanced emmetropic eyes by the use of eserin or atropin, or prisms or cylinders. Any abnormal condition of a secondary force—that is, any change in the *resistance* offered to accommodation, convergence, or torsion—may also produce a simple form of imbalance. Each primary force mentioned is so intimately connected with its secondary force that it would be confusing to attempt to separate them in this definition. An abnormal action of the vertical muscles only, may also produce a simple imbalance.

It is desirable, also, to have some term by which to indicate whether a force acting in a certain direction, or the

resistance to that force, is the more important cause in producing a given result. Therefore, when we speak of a *pure* simple imbalance, we understand that only the power of accommodation, or of convergence, etc., or only the resistance offered to that is greater or less than normal, in that individual case. If, however, one or more of the opposing forces or groups of muscles are at fault, we have a *mixed* simple imbalance. A good example of this is shown in an actual excessive esophoria in which there is also some insufficient action of the abductors.

Although simple imbalance can be produced artificially, it is also met with clinically. The examples of this which attract our attention most are perhaps those in which the imbalance of the insufficient form (a very slight paresis) follows an injury. But other cases of simple imbalance can be discovered by any one who will measure accurately the condition of the intra- and extra-ocular muscles.

A compound form of imbalance is one in which there is an abnormal condition of two or more principal forces or pairs of forces. In other words, it is some disturbance of accommodation with convergence or of both of these with torsion, either with or without a disturbance of the resistance normally offered to each of these principal forces. Abnormal action of the vertical muscles may also constitute an element in the production of compound imbalance. This too can be produced artificially. The large majority of all cases of imbalance are of the compound forms.

As accommodation is normally associated with convergence and both of these with torsion, so in normal conditions a disturbance of one of these principal forces is often associated with a like disturbance of one or both of the other principal forces. For example, we often find excessive accommodation associated with esophoria and insufficient accommodation with exophoria. We shall call these allied groups *associated compound imbalance.* Such cases are met with daily and they are mentioned here simply as a part of these elementary statements.

The simple forms of imbalance *merge into the compound* by gradual variations. There may be some decided anomaly

of accommodation, with a degree of heterophoria hardly measurable. Or the same individual may develop later a still greater degree of heterophoria, with proportionately less of the anomaly of accommodation. The two following chapters are devoted to the study of the simple forms of anomalies of accommodation and convergence, as through them we can understand better the compound forms. The student of mechanics, for instance, does not try at once to master the details of a triple expansion engine. He begins with the simplest form—preferably with an engine which he can construct for himself. When trying to obtain a clear idea of muscle imbalance, the student can find, or can artificially make, cases in which the problem is reduced to its simplest terms. Such cases are to this branch of ophthalmology what the Rosetta stone was to the hieroglyphics.

§ 5. **Imbalance should not be Confused with its Results.**—As the failure to use words which convey exact ideas is doubtless an important cause of our present confusion concerning this subject, it is desirable to define one or two other terms often used for ocular imbalance and yet differing slightly from it. Thus:

Eye-strain is a *result* of ocular imbalance. A person *may* or *may not* be conscious of the existence of any such strain, although its effect may be distinctly apparent. This cause and its result are so intimately associated that in most cases imbalance is considered synonomous with eye-strain.

Asthenopia is a group of symptoms, also the *result* of a muscle imbalance. The patient *is* conscious, often to a painful degree, of such symptoms. In this restricted sense the term can still be useful.

Megrim or migraine is practically a sick headache. The term has been used, as Head says (B 1114), in an exceedingly loose manner. Usually it means an attack of headache associated with decided gastric symptoms. Some writers, however, use the term to describe any headache, no matter how slight. On the other hand, several prominent French authors include under this term headache with vomiting, syncope, and even ocular paralyses. Evidently we would be

better off if we could strike out the word entirely and use the English term sick headache. It is more definite when there is a headache alone to specify that, giving its locality and degree of severity, or if there is a headache with nausea or with vomiting, to specify that also. Until that is done, much of our present confusion as to this symptom must continue.

§ 6. **The Cardinal Symptoms of Ocular Imbalance.**— Before attempting to study in detail the forms of imbalance which appear in the foregoing table, let us consider very briefly the symptoms which accompany some or all of them. We shall thus obtain a clearer idea of the clinical picture presented, and also avoid the necessity of constant repetition. But in attempting such a description, we at once meet a difficulty in the difference of opinions among ophthalmologists. For example, some consider that only a very few symptoms properly belong to imbalance or to eye-strain; others make the number a little larger, and still others imagine that every ill that flesh is heir to comes directly or indirectly from the eyes. Therefore, as the plan in this study is to advance cautiously, we shall deal here only with those few symptoms which all practitioners agree do frequently accompany imbalance. These may be called the *cardinal symptoms*. Then, as every symptom is, in a certain sense, also a sequela of a pathological condition, it will be permissible and much more convenient to consider in a later chapter some of the frequent concomitants of imbalance as sequelæ, and not as symptoms.

The cardinal symptoms of muscle imbalance with the resulting eye-strain are:

(*A*) **Blurring or Indistinctness of Vision,** especially after any protracted effort at accommodation. The type of this is the imperfect vision noticed in presbyopia or in hypermetropia. It is easy to understand how this occurs. For, as accommodation is essentially an active effort, the indistinctness is ordinarily due to insufficient focusing. It is only necessary here to call attention to this symptom, and its explanation. More extended reference will be made to it when considering excessive and insufficient accommodation.

(*B*). **Headache.**—The varieties of this are almost innumerable. The degree may vary from a slight discomfort which is hardly noticeable, to a pain which is unbearable and accompanied perhaps with gastric symptoms. This is the familiar sick headache. The location of the headache also varies. Although usually of the frontal type it may be referred to the vertex, occiput, or extend from that point down over the neck even to the back. Zimmerman has made a careful study of headaches accompanying imbalance and has found (B1116) that this symptom was present in 71.3 per cent. of all these cases.

At this point it is better simply to mention headache as one of the symptoms usually present even in the simple form of imbalance. When we study headache more in detail, we shall find that there are three forms to be recognized,—one caused directly, another indirectly by accommodation, and a third which may be called a reflex.

(*C*) **Hyperæmia of the Conjunctiva.**—Although this is not always present it is found so frequently as to be considered usually as one of the cardinal symptoms.

(*D*) **Increased Lacrimation.**—This symptom is seldom present in a very marked degree. In occasional instances, however, the association between it and imperfect accommodation is very striking. The overflow of the tears may be so constant and abundant as to indicate a stenosis of the lacrimal canal, but it may lessen or even disappear with the wearing of suitable glasses. In a slight degree, it is quite common.

§ 7. **How Cases of Imbalance should be Examined and Recorded.**—It goes without saying that it is desirable to make each examination in such a manner as to obtain the essential points promptly, and to secure ultimately a complete record. Every ophthalmologist of experience has worked out his own plan of examining and recording muscular anomalies, the object of each being to provide for an examination which is systematic, which is sufficiently complete for practical purposes, and in which the data are so arranged that they can be easily referred to when that patient returns, or readily compared with records obtained from other patients. It is not claimed that the plan of

examining and recording which is here given is the best, but only that it has been found useful, with certain modifications, in more than four thousand such cases.

A reduced copy of the blank used for this purpose is given on pages 14 and 15. In order to understand it, let us suppose for a moment (what is impossible) that a complete examination can be made at the first visit. The plan would be as follows:

Commencing with the date, name, residence, occupation, and age of the individual, we note the history, which need not be long, make record of the glasses, if any, which have been used for distance and near point, and the vision obtained with them. In the objective examination we follow the usual order, considering the parts from without, inward; noting in the space marked "anatomical" any peculiarities of the conjunctiva, cornea, etc., and especially of the fundus. Record is then made of any evident deviation shown by the reflections from the cornea and the size of the angle alpha (Vol. I, p. 130), of the length of the base line (Vol. I, p. 216), of the curvature of the cornea as measured by the ophthalmometer, of the position of the lens with the modified ophthalmometer (Vol. I, p. 69) or with the ophthalmophakometer of Tscherning, and also an estimate with the shadow test. These examinations reveal some of the obstacles which the ciliary muscles have to overcome.

As to the subjective symptoms, we naturally ask first about the headaches, and note their nature briefly or completely as desired. In entering the degree of the pain or discomfort experienced, it is better not to use adjectives, but to indicate its degree with numbers as we do that of tension, that is 1, 2, and 3, meaning, slight, moderate, or severe. It also furnishes a standard for comparison to note the number of minutes the person can read, on the average, without glasses or with them.

Next we come to the test of vision without a cycloplegic and the correction of any ametropia which may be discovered. We write the vision of the right eye, for example, and after that the formula for the best correction obtainable for it; then the print which can be read at the proxi-

Date.	Name.	Residence.	Occupation.	Age.

History.

Has Glasses for Distance { R. L.

For Near { R. L.

Objective Condition.

Anatomical.

Cor. Reflex.

Angle alpha.

Base line.

Kerato-metry. R. L.

Phaco-metry. R L

Retin-oscopy R. L.

Condition.

Smarting etc.
Pain in Eyes.
Head-ache. Frontal. Coronal. Occipital.
Nausea.
Other Sympts.

Can read without glasses.

With glasses.

Refrac. and Accom.

R. V —
R p. —
L. V. —
L. p. —

Relative A

M A	
0	
1	
2	
3	
4	
5	

Subjective	Extraocular	Date.	Static.							Dynamic.					
			M. A	Orth.	Es.	Ex.	R. H.	L. H.	Cyc	Add.	Abd.	Sup d.	Subd.	Int.	Ext.
			0												
			3												

Torsion with Convergence.	1	2	3	4	5	6	7	8
40								
20								
0								
20								
40								

Field of Fixation
R
L

Extra & Intraocular with Cycloplegic

Date. R. V. = R. p. =
Cycloplegic.
Amount.
After Minutes. L. V. = L. p. =

0													Without Correction.
0													With "

General Condition? Weight
Nervous System?
Muscular " ? Dynam. R. L. General Strength in foot pounds
Digestive " ?
Circulatory " ?
Other Disorders ?
Remarks

Provisional Diagnosis.

Final Diagnosis.

Case No.

mate point (R. p. =), filling out there also the formula for the best correction. When that is done for each eye, it gives, of course, an idea as to the power of accommodation. Also we can note in a similar manner the relative accommodation. It is easy, as we have found, to obtain the positive part of the relative accommodation with parallel visual axes, by simply ascertaining if the patient can read the distant types as well through certain concave glasses as without them. In emmetropia, up to middle life, this should be about — 3. D, and the necessity of using another glass indicates an imperfection of the ciliary muscle. If we wish to obtain a general idea of the range of relative accommodation, that can be done with glasses from the test case placed in the ordinary frame, the results being entered under "Relative A." In that small column the figures 1, 2, 3, etc. mean the amount of convergence in meter angles. If the results of such rough measurements, or other facts, indicate some imperfection in the range of relative accommodation, then exact measurements may be made of this and the results entered in the blanks already described (Vol. I, p. 317).

Having thus obtained our data concerning the refraction without any cycloplegic and approximately concerning the power of accommodation, we may pass to the extrinsic muscles. First we test the static (Vol. I, p. 214) and then the dynamic conditions (Vol. I, p. 300), either with parallel visual axes, to be entered on the line marked 0 (meter angle), or with convergence at $\frac{1}{3}$ of a meter, to be entered on the line marked 3 (meter angles). Or, if these rough measurements, or other facts, point to some imperfection in the range of relative convergence, then exact measurements may be made of this (Vol. I, p. 341) and the results entered on the blanks already described (Vol. I, p. 344). In a similar manner a rough examination should be made of the torsion. The results of this can be entered on the co-ordinates which are printed on that part of the blank. The horizontal line 0 is supposed to represent the horizontal plane. The numbers 15 and 30, reading up, are degrees of the inclination of the visual plane above the horizontal. Or similar numbers show the depression of the visual plane below the horizontal.

The figures above the ordinates (1–2–3, etc.) indicate the amount of torsion which is found to exist when the tests are made with a given amount of elevation or depression of the visual axes. In these tests it is desirable for the sake of uniformity to have always the same degree of convergence, and this is accomplished if the same instrument is used—for example, the tortometer (Vol. I, p. 356).

If it is desired to measure the field of fixation with the perimeter or tropometer, the results, at least as far as the principal meridians are concerned, can be entered on the small crosses R. and L. for the right and left eyes respectively.

Such an examination up to this point gives the objective and subjective condition without the assistance of a drug. If a cycloplegic like atropin is to be used, the amount and the method of measurement depend on whether we wish to test the refraction or to measure the strength of the ciliary muscle. It is easy enough, as we know, to determine the refraction if we will simply use a cycloplegic which is sufficiently strong. It is well to note which cycloplegic is used, the amount which has been applied, and how many minutes elapsed before the examination was made. Our studies of the effect of minimum doses of cycloplegics and myotics (Vol. I, p. 154) have taught us, however, that the data thus obtained are in certain cases, at least, quite as important as those from full doses. When such measurements are made, the results are entered on the special blank already described (Vol. I, pp. 158 and 159). It will be noticed that on the record blank, in the part relating to the action of the cycloplegic, there is entered R. p. and L. p. This is to indicate the proximal point for the right and the left, respectively, at which the smallest print can be read. At first glance it may seem quite unnecessary to make any measurements concerning the near point after applying to the conjunctiva what is supposed to be a full dose of a cycloplegic. Many a practitioner is accustomed to think that if he uses what he considers a "sufficient" dose of homatropin, or surely of atropin, by dropping this into the eye a few times, therefore the accommodation must be entirely at rest. Unfortunately that supposition is often wrong. Any one who

will take the trouble to use a definite amount of the cycloplegic in the form of discs, and then test the eyes at a certain time after the application not only for the far but for the near point also, will find decided differences in the behavior of ciliary muscles.

In certain cases it is desirable to measure the actual static condition—that is, the position of rest when accommodation is eliminated by a cycloplegic. (Vol. I, p. 240.) On the blank there are two lines for entering the records for these figures. The first shows the condition without correction of the ametropia, and the second, with that correction. Instead of repeating the headings for orthophoria, exophoria, etc., after a cycloplegic has been used, it is more convenient simply to enter these conditions directly under the corresponding headings printed on the blank farther above. These tests, evidently, are necessary in exceptional cases only.

All of the foregoing relates to the optical part of the examination. But as morbid conditions of the general system or of special organs are often of importance in this connection, all such blanks should have space on which to make at least some notes of that aspect of the case. The heading "General Condition" refers to the nutrition, weight, and is for remarks on assimilation. As to the nervous system, it is important to observe whether that is apparently normal. or whether we have to do with a neurotic, or with evidences of hysteria or chorea, whether the patellar reflexes are normal, or other details of a similar kind. Concerning the muscular system, the measurements given by a dynamometer, as shown by the pressure of the right hand (R) or the left (L) are easy to note. Or it is often desirable to enter the general strength as expressed in foot-pounds, although the details of this fill a special blank.

In regard to the digestive condition, memoranda may be made of the appetite, regularity of the bowels, etc., although of course the results of examination of the stomach contents are entered on a special blank. If there is anything abnormal about the circulation, that can also be noted. But the results of examinations of the blood or urine, or descriptions of

similar morbid conditions, are also entered in detail on more complete blanks. After all of our data have been collected, and not until then, are we ready to enter the diagnosis. At a first visit we should enter only a *provisional* diagnosis, as any one who has had a large experience in this class of cases appreciates that the first diagnosis is not always the right one.

It is convenient to write the number of the case at the bottom of the blank and also to repeat there the name, as when these blanks are filled, this brings the number and name in the place where they can be most conveniently found.

But, perhaps it may be asked, is it expected that a practitioner will go over all these details with every patient who has a difficulty with the ocular muscles? Of course not. That is not only unnecessary in routine cases, but evidently impossible. What one really does, is to begin with the more essential points, determine them, and record them as rapidly as exactness will permit. As soon as sufficient data have been obtained, we arrive at a provisional diagnosis, more or less complete, and that and the prescription is recorded. That patient is then bowed out of the office, and the next one called. But as the facts must be entered somewhere, it is convenient to have blanks like the preceding, or similar to it, so arranged that the data may be available for future reference. The truth is, too, that although one may arrive at a provisional diagnosis at the first visit and give a prescription, a certain proportion of patients are certain to bring back their complaints of continued discomfort. For such cases the blanks referred to are specially adapted. When these patients return it is our duty to complete the examination gradually from time to time as opportunity permits, and to do it with all the exactness which the present state of our knowledge will allow. This may require one additional visit, or half a dozen or more. Certain obscure cases require examination with cycloplegics or myotics, or both, in minimum and in maximum doses, and indeed, each such case becomes a study in itself, before it is possible to distinguish the separate elements and their relative im-

portance in the production of the symptoms of which the patient complains.

It may be objected, however, that any such detail requires the aid of an assistant. In part that is quite true. But it has nothing to do with the necessity of thorough examination nor of exact records. A patient has a right to demand that. In some localities the surgeon is expected to complete personally all the details of examination. But patients, and indeed a community, can be taught that a competent assistant can save the time of the surgeon and therefore the cost to the patient. A medical student or some young physician is not always the most desirable assistant. If he is ambitious—and no other is good for anything—he is naturally interested in his studies or in broader views of the subject. The best assistant in this work does a few things intelligently, patiently, and thoroughly. If many cases are to be recorded or complete notes made, even of a few, some one who knows stenography becomes a necessity to a busy man. Routine examination of the blood, urine, stomach contents, etc., can be learned by almost any one, but when unusual exactness is required this must be done by some one especially trained in that work. A surgeon in active practice who attends to all the details himself must necessarily sacrifice valuable time to minutiæ, and the sooner he leaves the collection of certain data to others, and devotes his own energies to studying the relative importance of those data in the special case, the better it will be for the patient, for the practitioner, and for the advancement of our science.

SUMMARY OF CHAPTER I.

In Darwin's *Origin of Species*, at the end of each chapter or series of chapters a summary is given of the leading facts to which attention has been called. The example of that eminent teacher is worthy of imitation, for such a summary enables a writer to review the salient points free of all encumbrances.

It did not seem necessary in the first volume to make

these summaries, for there we were travelling over a more beaten path. But now we are entering a tangle of pathological data, and as we attempt to blaze the way, at least in places, it is well to halt frequently and take our bearings, lest we wander from the solid foundation of fact into the quicksands of theory.

Therefore a brief resumé will be given at the end of most of these chapters, and in the final one a recapitulation can be made. It will thus be easier to see the basis for our conclusions.

The principal object of this first chapter has been to agree on definitions. We began by recalling the fact that in muscle balance with comfortable binocular vision, the accommodation, convergence, and torsion bear their natural relations to each other, whereas in imbalance that is not the case. Although this definition might include even forms of heterotropia and paralyses, it was agreed that the term "ocular muscle imbalance," or simply "imbalance" should be reserved for those cases in which binocular vision is maintained and in which anomalies of the ocular muscles are not apparent without special tests. It includes the latent deviations. Attention was called to the fact that while this imbalance of the muscles is a fundamental pathological condition, eye-strain is a result of that condition of which the patient may or may not be conscious. The term "asthenopia," we decided, if used at all, should be restricted to a group of symptoms, also the result of muscle imbalance, of which the person is conscious, often to a very considerable degree; while an indefinite term like migraine should be discarded or its meaning defined.

We then took a general view of the field before us, glanced at the few cardinal symptoms of imbalance, such as constitute the discomfort of which patients often complain,—blurring of vision, headache, hyperæmia of the conjunctiva, and increased lacrimation. Finally we decided on a plan for the examination of cases of imbalance, and arranged a blank on which the data can be conveniently entered.

CHAPTER II.

SIMPLE IMBALANCE INVOLVING ONLY THE INTRAOCULAR MUSCLES.

ANOMALIES OF ACCOMMODATION ONLY (SIMPLE HETEROCYKINESIS).

DIVISION I.

ACTUAL EXCESSIVE ACCOMMODATION.

Introductory Note.—As the ability of the ciliary muscle to change the form of the lens must be either what we call normal or else greater or less than normal, we are now to study in turn these different anomalies of accommodation when they occur alone—that is, not in combination with any other form of imbalance. These conditions for the most part can be produced artificially in normal eyes by drugs or by glasses, and are also met with occasionally in practice. It is desirable to study carefully these simple forms of imbalance at the outset. For if we make ourselves familiar with their symptoms and treatment, we shall find it much easier to recognize those forms of compound imbalance which we meet with daily, and of which these simpler forms constitute a part. It is convenient to begin our study with Actual Excessive Accommodation.

§ 1. **Definition.**—In this condition there is actually an excessive action of the ciliary muscle. Evidently this, when in marked degree, is what has long been called spasm of the accommodation. This term "excessive accommodation" has an advantage over the word "spasm," because in the earlier studies of this anomaly only extreme cases were recognized,

and the term "spasm" therefore conveys a wrong idea, both as to the frequency of the difficulty, and its degree.

We obtain a clearer idea of this, and of similar forms of imbalance by a diagrammatic representation—Fig. 2.

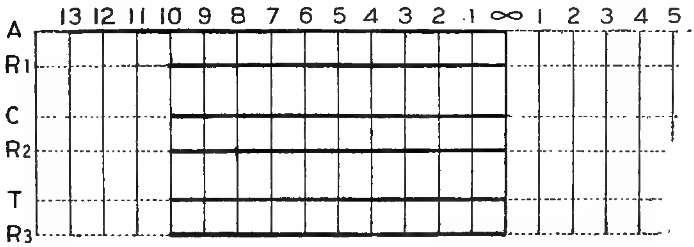

FIG. 2.—Representation of an actual excessive accommodation (spasm of accommodation) of 3 D. in an emmetrope.

Thus A represents the accommodation and R the resistance offered to it in an emmetrope twenty years old who has an actual excessive accommodation of three diopters. Instead of a range of accommodation from infinity to about 10 cm. in front of the eyes, as is usual for a person of that age, we find he can read the type at 7.5 cm. or has an accommodation of thirteen diopters. In this simple case all tests fail to reveal any heterophoria.

§ 2. **Varieties.**—The above definition, with the diagram, shows what actual excessive accommodation with emmetropia is. It might be supposed that this variety of excessive accommodation can exist only in a pair of emmetropic eyes. It is true that is the typical form of the condition and is the one represented in Fig. 2. But inasmuch as real emmetropia is so rare, it is safe for practical purposes to include cases in this list where the ametropia does not exceed half of a diopter. Now the examinations made by Schmidt-Rimpler (B 871) and the experience of most practitioners show that excessive accommodation is a frequent accompaniment of myopia and sometimes of hypermetropia. Such a case is seen, for example, in diagram Fig. 3.

Such an actual excessive accommodation which occurs with myopia or any other form of ametropia is not to be

confused with what we shall soon learn to be relative excessive accommodation. In the former cases:

(*a*) The near point is abnormally near.

(*b*) It can be made to recede permanently by the use of glasses or by a cycloplegic.

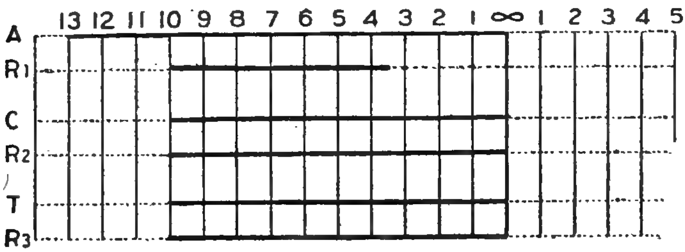

FIG. 3.—Representation of actual excessive accommodation of 3 D. in a myope of 3.5 D.

On the contrary, in relative excessive accommodation, we shall find:

(*a*) The near point is at a normal distance for the age of the individual and

(*b*) It cannot be made to recede permanently by the use of glasses or by a cycloplegic.

Evidently we may have two varieties *in kind* of the condition under consideration, namely: actual excessive accommodation with emmetropia and actual excessive accommodation with ametropia.

Cases of excessive accommodation are also divided into two kinds, according to the duration of the spasm, whether this is of a *clonic* or of a *tonic* variety (B 328, p. 537). The former occurs only with convergence. In the latter, the spasmodic action is continuous, and is affected only by a cycloplegic or by convex glasses worn for a very considerable time.

Again, there may be varieties *in degree* of the condition under consideration, no matter whether the actual excessive accommodation is in a pair of emmetropic or of ametropic eyes, of a clonic or a tonic variety, or a combination of these forms.

Thus Schmidt-Rimpler would have a distinct difference

made between effort of accommodation ("akkommodations-spannung") and spasm of accommodation ("akkommodationskrampf"), and yet, after dividing these as clearly as he could, there arose a discussion between himself and Hess (B. 873) as to whether the terms were properly employed. This gives an indication of the difficulty not only of separating the different stages of so-called spasm from each other, but also of recognizing them after that separation is made. Nevertheless, we should understand that such gradations in the amount of the spasm do occur, in different individuals, or indeed in the same individual at different times, and that for clinical purposes these differences should be recognized as clearly as possible.

§ 3. **Frequency.**—It is difficult to make any exact statement concerning the frequency of typical cases, for the reason that apparently no study of that point has yet been made. On the other hand, the existence of this condition in the higher degrees of ametropia—especially with myopia—has been frequently investigated. Since Donders wrote his chapter on Spasm of the Accommodation (B 260, p. 610) and Landolt followed (B 328, p. 557), various studies have been made of its occurrence, especially among school children. Even though these were cases of excessive accommodation with ametropia, they give at least some idea as to the frequency of the condition with emmetropia.

The large majority of the modern writers agree that some spasm of the accommodation is decidedly common, especially in school children. Thus Stocker (B 385, p. 263) found it in five per cent. and Schmidt-Rimpler in from ten to thirty per cent., according to the refraction. Among myopic children this condition is apparently even more frequent. In one lot Schmidt-Rimpler found it 4 times in 6, again 7 times in 11, or even 9 times in 10.

Not unfrequently, when the test case shows a higher degree of myopia than the ophthalmoscope, if atropin is prescribed we find that the apparent myopia disappears in part. Sometimes this difference is not apparent the first day or the second, but when the atropin is continued long enough to make the throat dry, it is no unusual

experience to obtain then as good vision with a decidedly weaker concave or stronger convex glass, and very often with at least partial relief of any symptoms of discomfort.

It is true that sources of error must be taken into account. Measurements made with the ophthalmoscope only are not altogether reliable. With subjective tests, especially among children, the replies are contradictory; such patients are often notional or hysterical, and, above all, the term "spasm" of accommodation, as generally used, is too restricted. For that reason we must be careful in accepting statistics on this point unless all the details are fully stated. But in view of the facts before us, we must conclude that while the slight degrees are doubtless common, at least among school children, and especially among those who are myopic, the moderate degrees, and certainly those which are severe, are rare.

Cases of actual excessive accommodation with a low degree of astigmatism are frequent. Every ophthalmologist recognizes at a glance the clinical picture of the young woman of the chlorotic and perhaps the neurotic type, who brings a story of the cardinal symptoms of imbalance and many other ills of various sorts; she also shows a pair of glasses which have been prescribed for her, these being —0.5 or even —0.75, axes nearly or exactly horizontal. The first rough test of the refraction which we make shows that apparently there does exist an astigmatism of this kind and degree. That opinion may even be fortified by the results of a full dose of homatropin applied as it is ordinarily used. The patient persists in refusing convex cylinders with the axes vertical. But in such a case more careful tests with minimum doses of atropin or with eserin indicate a spasm of the accommodation. If we then prescribe atropin and send such a patient home for a week or two, and perhaps at the same time continue with the same plan of tonics and other treatment which she had for her general condition, we find at the end of this short time that she is quite ready to accept a weak convex cylinder with the axis nearly or quite vertical. The headaches and other discomforts also have lessened or disappeared. She is en-

couraged to follow out other phases of the treatment, which by improving her general condition remove the remote causes, and the surgeon feels assured that recovery is not far distant. It gives a wrong idea to speak of such a case as "spasm of the accommodation" as that phrase is ordinarily understood. But there is every reason to group these cases together in a class nearly allied to those of spasm and call them cases of actual excessive accommodation.

§ 4. **Symptoms.**—(*A*) The range of accommodation is not normal.

(*a*) The near point is too close to the eye. The method of measuring this accurately has been described (Vol. I, p. 154) and the standard of comparison shown (Vol. I, p. 335).

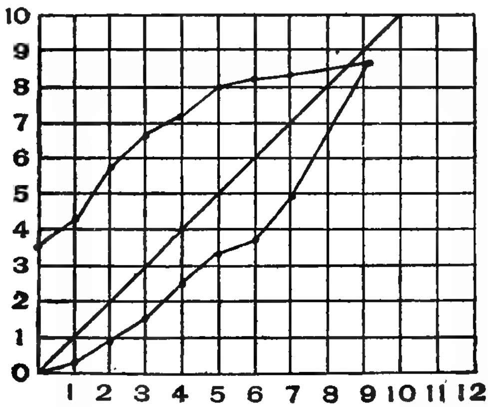

FIG. 4.—Relative accommodation in actual excessive accommodation of low degree (0.5).

(*b*) The far point also may be approached—that is, there can be an apparent myopia. When the vision is tested for the far point, the patient may not be able to read $\frac{6}{6}$, but can do so with a concave glass, usually a weak one. In spite of this characteristic appearance of myopia, we may find, when atropin is used, that we have an emmetrope, or at least that the apparent myopia is perceptibly less.

(*B*) The relative accommodation is altered (Fig. 4).

(*a*) The positive part of the relative accommodation is increased. This is shown even with parallel axes, when no apparent myopia is present. One of the essential parts of a rough examination is, as already mentioned, to place a—3 D. before each eye and ascertain if the patient can read the distant test-types as well with these glasses as without. (Vol. I, p. 339.) With convergence at three or four meter angles, the minus glass which can be overcome is stronger than usual. When making these measurements clinically, it is convenient and quite accurate to have the bar of the optometer attached to a handle as represented in Fig. 4 a.

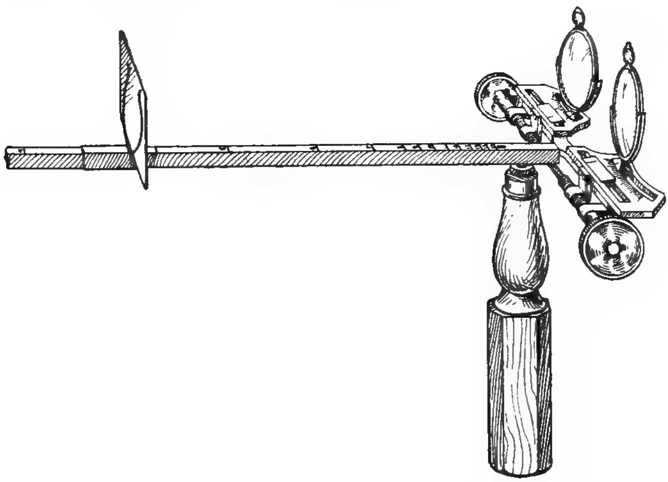

FIG. 4 a.—Optometer of the author arranged for clinical examinations.

(*b*) The negative part of the relative accommodation is abnormally small. With parallel visual axes the patient may require a concave glass to see distinctly.

(*c*) A minimum dose of atropin does not produce its effect with the usual promptness or completeness (Fig. 5). This is noticeable:

(*a*) In the accommodation.

If a disc containing about .00001 gram of atropin is placed on the conjunctiva, we find that relaxation does not begin at the end of thirty minutes, nor even at thirty-five or

forty. If we plot the curve which represents the change, we find the line remains almost horizontal for a considerably longer time than in the normal condition. The fall, when it does begin, is gradual, and it does not reach the

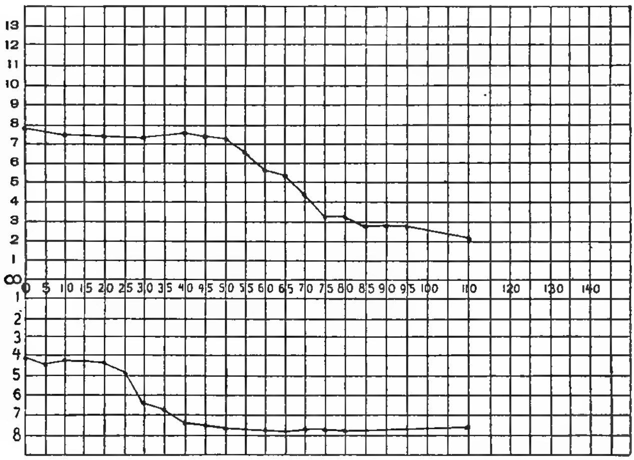

FIG. 5.—Immediate effect of a minimum dose of atropin sulphate in actual excessive accommodation.

usual limit, nor does it remain at the lowest point as long as with the normal eye, after the use of even that small dose.

(*b*) A corresponding peculiarity may be presented by the pupil. It should be observed that under any circumstances, the pupil in this condition is not ordinarily one which may be called active. It is often small in proportion to the age of the individual, and when watched for a minute or two through the horizontal microscope it does not show the usual number of full contractions and dilatations. After the application of the disc of atropin just mentioned the pupil does not dilate as promptly as is usual—nor to so great a degree.

(*D*) A minimum dose of eserin usually produces its effect promptly and completely. This is seen in Fig. 6.

(*a*) In the accommodation. If a disc containing about 0.00001 gram. of eserin is applied to the conjunctiva, we

find that unusually soon after the application the curve which represents this rises rather more rapidly, reaches a higher point, and remains there a longer time, proportionately, than in the normal eye.

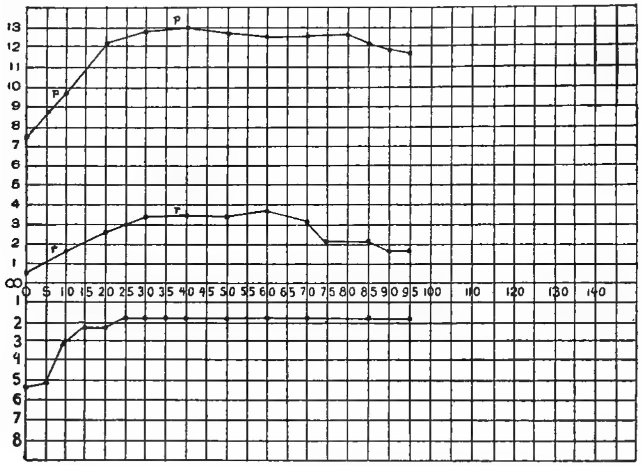

FIG. 6. Immediate effect of a minimum dose of eserin in actual excessive accommodation.

(*b*) The effect of such a dose upon the pupil usually corresponds to the effect on the accommodation, but this also is not constant. The contraction does not begin any sooner, apparently, than after a similar application in the normal eye, but the effect is usually more marked both as regards the rapidity with which the contraction takes place, the degree which is reached, the length of time which the contraction continues, and the slowness with which the effect disappears. In view, however, of the varying susceptibility to cycloplegics and myotics, absolute reliance can not be placed on these indications, but the data which they furnish in the average case are always suggestive, and usually can be counted on with considerable confidence.

(*E*). Wrinkling of the forehead. Efforts of the ciliary muscle which accompany excessive accommodation or which are indirectly the result of insufficient accommodation call into action the accessory muscles, and there occurs some-

times a scowl or wrinkling of the forehead which is quite characteristic.

This is seen in most persons when for a moment a strong effort of accommodation is made. The permanent wrinkling probably depends upon several different factors, as, for instance, the relative development of the accessory muscles, their variation being often the result of hereditary tendencies. The amount of adipose tissue in that individual may or may not have absorbed sufficiently to allow the wrinkles to become permanent. But when any causes conspire to produce a contraction of the accessory muscles of the forehead there results a facial expression which is quite diagnostic. When this affects only, or principally, the muscles involved in accommodation, we find that the wrinkles are, for the most part, vertical. Starting from the root of the nose they pass directly upward, or even radiate from that point up and outward in fanlike fashion. This is seen in Fig. 7.

FIG. 7. Vertical wrinkles in the forehead produced by efforts at accommodation.

(*F*) The subjective symptoms of excessive accommodation are the cardinal ones of imbalance, with perhaps some few reflexes. They are all usually slight in proportion to the degree of the spasm. The explanation of this is not difficult. In the physiological part of this study we have seen the truth of the fact on which Donders insisted—that, as a requisite of comfortable vision, the positive part of the relative accommodation must be larger than the negative part. (Vol. I, p. 338). That is exactly what we find here. The positive part is larger, sometimes indeed much larger, than

the negative part, but usually little or no inconvenience results.

§ 5. **The causes** of actual excessive accommodation may be local or general.

(*A*) The local causes are :

(*a*) Myotics. It is easy to transform a pair of emmetropic eyes with comfortable vision into those which present a typical clinical picture of excessive accommodation, by applying to the conjunctiva a suitable dose of eserin. Such cases, although artificially produced, should be mentioned first because we know the cause so exactly. If a certain amount of eserin is applied to each eye of an ametrope the clinical picture which results is that of excessive accommodation modified by the ametropia in that individual. For the purposes of the student, therefore, myotics occupy a prominent place among the causes of the condition under consideration. (B 880–881.)

(*b*) Excessive effort of accommodation for a considerable time undoubtedly tends to produce this condition. Our cases do not come from those who lead an outdoor life. They are professional men, book-keepers, stenographers, seamstresses, and those of similar occupations. We do not know why such a condition of the ciliary muscle develops in certain persons, while others who have the same occupation and apparently the same surroundings are entirely free. The problem of individual susceptibility is as far from solution in this case as in innumerable others which the practitioner meets with every day. The evidence seems to show, however, that remote causes such as accompany a sedentary life, form an important factor in the question. However that may be, the fact remains that persistent use of the eyes for near work tends to produce this excessive accommodation. (B 874–879.)

(*c*) The glare of a strong light may also cause it. (B 865.) When arc lights are not properly protected and especially when they are allowed to flicker this often occurs. If certain persons attempt to read rather fine print by such an arc light, they find after a time that it is necessary to bring the type perceptibly nearer to the eyes. In other words, a temporary

excessive accommodation has been produced. The reflection of sunlight on the water, or on an expanse of sand, or the so-called snow-blindness often produces this condition. In some individuals the symptoms of excessive accommodation continue a long time after any or all of these exciting causes have been removed.

(*B*) The general causes are not well defined, but among them are:

(*a*) Primary diseases of the nervous system in which, at certain stages, at least, there is a contraction of the pupil due to irritation of the third nerve and not to paralysis of the sympathetic. Thus in the earlier stages of tabes we find contracted pupils in from 36 to 45 per cent. (B 873 *a*) or more, and among these eyes a very considerable proportion exhibit actual excessive accommodation. Also, in one stage of multiple neuritis, and in paresis, among the patients whose pupils are small, a certain number present typical clinical pictures of this same condition.

(*b*) Reflexes from stomach or elsewhere. We know that irritation of a sensitive nerve causes increase in blood pressure, though we do not know how that is accomplished. We also find that a considerable number of irritants produce an effect upon the muscles of accommodation and also on convergence, though we do not know how. For example, a morbid condition of the stomach will produce in one child choreic movements or convulsions, in another esotropia, and in a third an actual excessive accommodation. These are frequently the result of hyperacidity. Other sources of irritation accompany contraction of the ciliary muscles, and for lack of a better term we class these as "reflexes."

(*c*) The toxemias. It is not easy to define exactly what is meant by this term, especially when used in such a connection, but we know that imperfect elimination through the alimentary canal, the kidneys, or the skin is followed sometimes by actual excessive accommodation ; sometimes also by exactly the opposite condition.

§ 6. **The Prognosis** varies according to the cause, being naturally more favorable when that is of a local rather than of a general character. Much depends also upon the degree

of the spasm. When excessive, as in the rather rare cases which are due to a central lesion, the prognosis is decidedly unfavorable. But in the class of cases which occupies our attention especially—that is, those lighter forms which produce only slight muscle imbalance—the prognosis is favorable as regards the comfort of the patient, although in spite of this a certain amount of spasm may often still be detected by accurate methods of examination.

§ 7. **Treatment.**—(*A*) The local treatment of this condition may be expressed by the single word—*rest*. This means rest from any occupation which acts as an exciting cause, rest of the ciliary muscle such as is possible by means of convex glasses, and above all, rest by means of a strong cycloplegic continued during a considerable time.

Occasionally when this form of imbalance occurs alone, and frequently when it occurs as a component part of compound imbalance, the so-called "blurring" plan of treatment is of decided advantage. This means nothing more than constant over-correction with convex glasses and therefore more and more enforced rest of the ciliary muscles.

In this connection a question might arise as to whether cycloplegics should be used in order to determine the refraction, and after that whether it is ever necessary to make the correction with perfect accuracy. These are two questions of practical importance, and although it is not usually necessary to consider them carefully in cases where only the accommodation is involved, still if we answer them definitely at this point, it saves much repetition later.

(*a*) As to the necessity of using cycloplegics in order to determine the refraction, the differences of opinion are more apparent than real. On the one hand, we have the optician's experience that cycloplegics are entirely unnecessary—probably because he is prohibited in most countries from using them. But his experience in correcting errors of refraction is often so great that we cannot honestly ignore his testimony. Moreover, patients constantly bring from the opticians glasses which have given perfect satisfaction for a long time.

In many clinics, especially in Europe, where the number

of patients is large and the cases of ametropia are usually dealt with more superficially than here, we often find very good results obtained without cycloplegics.

Finally, there are theoretical objections to their use. Our aim is to test the condition of the eyes as they are in action, not as they are when artificially at rest, and, moreover, we do not need to know the refraction of the parts of the lens which are normally covered by the iris.

On the other hand, it will be admitted as beyond question that the full dose of a cycloplegic does furnish additional data, especially as to the real amount of a suspected hypermetropia or hypermetropic astigmatism. It will also be admitted that in most cases, when the suffering from persistent pain is considerable, it is desirable to obtain all the data possible. The arguments for and against cycloplegics can be summed up by saying that while it is possible to obtain an accurate and satisfactory correction of the ametropia without a cycloplegic, it is certainly more difficult to do so than with its assistance, and taking into account the inconvenience to the patient, it is simply a matter of judgment in each case whether its use should be advised or not. The practice of invariably resorting to a cycloplegic is as reprehensible as not to use it at all. The question must be determined by the peculiarities in each case, by the degree and persistence of the symptoms, by the occupation of the individual, and the inconvenience he would suffer by interrupting his occupation even for a day.

One or two further observations should be made concerning this subject.

As to the selection of the cycloplegic for determining the refraction: It is evident from what we have found in our study of the physiological action of these drugs that without some care we are apt to fail in the object for which the full doses are employed. If we wish to obtain complete relaxation of the accommodation, homatropin is not always reliable. As this is ordinarily used, it often does not produce complete relaxation of the ciliary muscle, especially if there is any spasm present, and even if the relaxation does occur, the tests must be made just at

the right time or the full effect of the drug may have disappeared.

If we wish to obtain results which are constant, and which can be compared with each other, no matter what cycloplegic is employed, we should use by preference a disc, or if a solution is preferred then it should be always of the same strength and used in the same way. The ordinary habit of applying to the eye a few drops of homatropin of any convenient strength, then at intervals of a few minutes applying it again and again, is unscientific in method and unsatisfactory in result. It is true that the pupil dilates, and that we obtain *a certain amount* of relaxation of the accommodation, but there is even more than the usual doubt as to whether that relaxation is complete. We do not know how the effect compares with that obtained in other cases, nor is it possible by this method for different practitioners to compare their results as a whole with each other. The evident remedy for this confusion is to select a standard preparation for each drug, being certain that it is so strong that a single disc will, under physiological conditions, produce complete relaxation of accommodation. For atropin this should be about 0.00013 gram ($\frac{1}{500}$ of a grain) and for homatropin about 0.0013 gram ($\frac{1}{50}$ of a grain). We should apply this to the conjunctiva once and once only. Then we should wait for at least an hour after the application before beginning the tests. In this way it is possible to compare results. It is true that complete relaxation may not have occurred with this amount of the drug, but if so, that fact is of diagnostic significance. This has proved a more accurate and satisfactory method than that of hurrying to obtain a result immediately, leaving an unnecessary doubt as to the very point for which the measurements are made.

(*b*) Is it desirable to make a really exact correction of the ametropia?

To this question we may give an unqualified affirmative answer. This is a conclusion which we have been reaching slowly, but I think in America, at least, it is one which expresses almost unanimously the sentiment of ophthalmic

surgeons. A quarter of a century ago, even in this country, it was deemed quite sufficient to correct the ametropia approximately and to let the case go at that. Gradually we have learned better. Among the first to call attention to the advantage of a weak convex glass were Norton and Chisholm (B 882–887). When the latter published his first article to show the important results obtained by the use of + 0.5 D. sph. and + 0.5 cyl. the statements were received with incredulity. It was difficult to believe that so weak a glass could have any effect upon the existing imbalance, and the result was attributed in general to the mental effect on susceptible persons of wearing some sort of glass. That such susceptible cases do occur there can be no doubt, but it is also certainly true that a variation of a quarter of a diopter (0.25) may give decided relief from an eye-strain, especially if the glass is a cylinder. Nor are these persons always of the hysterical type. A well marked example of this was a patient of unusual intelligence who was familiar with lenses and who, when he came at first, quite ridiculed the idea that these very weak glasses could have a decided effect. But repeated experiment upon his own eyes convinced him of the fact.

In a word, therefore, while a rough approximation in the number of the glass may be necessary at the first visit, we should not be satisfied with that, nor allow the patient to be, if the symptoms are severe or persistent. In that case we should make the correction as accurate as our methods of examination will allow.

(*c*) Bifocal glasses are often of great assistance or even essential. After middle life, or sooner, if efforts at accommodation become difficult, a great deal can be gained by the use of such glasses. Theoretically this is easy to understand, but until late years it was not possible to carry out the idea, because of the imperfect manner in which bifocals were made.

We now have such glasses in which both the anterior and posterior surface is perfectly smooth, the extra curvature being gained by a disc of different density inserted between the outer plates. It is a disadvantage and discredit

that several of these devices are controlled by patents, but they have added to the comfort of patients, and should thus be noticed in any general summary of the subject. In some cases toric lenses seem to prove more acceptable than those ground in the ordinary form, and as the additional cost is insignificant a trial of them is often desirable.

(*d*) The constant use of a cycloplegic. Years ago Donders called attention to the fact that it was necessary not only to use belladonna, but also to persist in the application for a long time. One case which he gives (B 260, p. 625) is particularly instructive. The symptoms were severe, and repeated trials of belladonna for a month or two gave little or no relief, but after it had been continued for six months complete cure resulted. Such a well-trained observer would not be easily misled by any other factor which might have entered into that question. In a word, actual excessive accommodation requires the use of a cycloplegic often for a very considerable time.

(*B*) The general treatment of these cases is also important, but a careful study of each one is necessary, as systemic conditions vary greatly. We may have the anæmic type, in which the spasm is dependent upon insufficient assimilation or nutrition. In these, tonics and out-of-door life are of course the first consideration. Or we may have quite a different type, in which there is apparent plethora due to sedentary habits and overfeeding. Alcohol or nicotine may be contributing factors, even though the amount of either consumed may not be actually great. In a word, the general treatment is indicated by the condition presented, and the ultimate result depends largely upon the patience and persistence with which these different causes are diagnosed, and one after the other eliminated from the problem.

CHAPTER II.

DIVISION II.

RELATIVE EXCESSIVE ACCOMMODATION.

§ 1. **Definition.**—In relative excessive accommodation the action of the ciliary muscle is practically normal, but the resistance offered to it is abnormally lessened. The ciliary muscle has not, relatively, a normal amount of work to do, and there remains an excess of energy in proportion to, or *in relation* to, the demand made upon it. In *terms of muscle imbalance* we thus speak of *a relative* excessive accommodation, though in *terms of refraction* we have to do with myopia in some form.

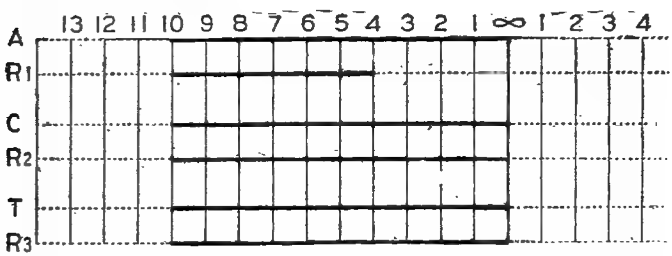

FIG. 8.—Representation of a relative excessive accommodation (myopia) of 4. D.

We can obtain a clearer idea of this form of imbalance if we represent it graphically as in Fig. 8. The excess of energy in a myopia of 4 D., for example, is appreciated if we consider that the ciliary muscle is relieved of all work while the eye makes one, two, and three meter angles of convergence.

§ 2. **The frequency** of this condition is apparent when

we remember that we are here dealing mainly with myopia or myopic astigmatism in some form, or rather its relation to the ciliary muscles. With that statement the question of frequency may be left, as it is discussed in every book on refraction.

§. 3. **The symptoms.**

(*A*) The range of accommodation is altered. The near point is not approached, but there is an approach of the far point, this depending, of course, upon the distension or distortion of the globe.

(*B*) The relative accommodation is altered. The relative accommodation of a myope of three diopters is shown in Fig. 9. As such a person does not make any accommo-

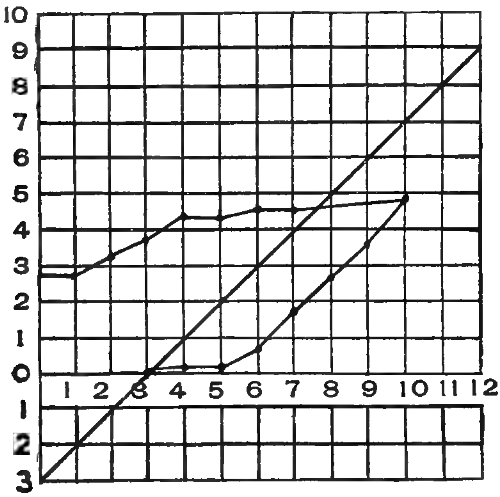

FIG. 9.—Relative accommodation in relative excessive accommodation (myopia).

dation with one or two meter angles of convergence, evidently when we plot the relative accommodation the diagonal showing the convergence starts from the horizontal zero line three spaces to the right of the first vertical. When testing the positive part of the relative accommodation with parallel visual axes this person could overcome concave glasses a little stronger than — 6. D. After the correction

was made for the distance between the glasses and the eyes, according to the formula (Vol. I, p. 320), and after deducting —4. D. it was found that the positive part of the relative accommodation was nearly 3. D. Consequently, in plotting this, we place the dot which indicates that point at a little below three on the first ordinate. This is where the curve begins, which shows the positive part of the relative accommodation.

The manner of measuring and then plotting the curves which represent the far and the near point of the relative accommodation with varying degrees of convergence has already been described (Vol. I, p. 317). But the fact which interests us here is, that after we have constructed these curves or lines—no matter by which method it is done—we find that the positive part of the relative accommodation is usually large as compared with the negative. We know already that where this exists, accommodation can be maintained ordinarily with little or no inconvenience (Vol. I, p. 338). The condition of the relative accommodation and the picture which is obtained by plotting it are exactly the opposite of what we find in hypermetropia. We shall see this later when we have to do with relative insufficient accommodation.

(*C*) The inconvenience experienced is remarkably slight in proportion to the degree of imbalance. This, as has been suggested, is because the positive part of the relative accommodation is so much larger than the negative. It is not easy to understand how the pure types of relative excessive accommodation—that is, cases of myopia, without any trace of heterophoria or other anomaly—can give rise to any discomfort. If such cases do exist, they are probably rare. Usually if any pain is present we have also some form of heterophoria or other anomaly. This may not be discovered perhaps until, with the accommodation entirely at rest, we measure the actual static condition (Vol. I, p. 240), or until we measure exactly the relative accommodation or convergence, or the torsion in various planes. When any such second anomaly exists, that of course removes the case from the group now under consideration and makes it a form of compound imbalance.

§ 4. **The treatment** of this form of simple imbalance resolves itself into a question of restoring the muscle balance by a proper correction of the myopia and myopic astigmatism. It is beyond our scope to enter into details concerning refraction. Therefore we have nothing to do directly with the restoration of vision to the myope, nor the method of accomplishing it, nor whether it is better to have the correction of the myopia partial or complete. The problem before us is how to restore the muscle balance. If we had to deal only with simple forms of imbalance we could take into consideration the ciliary muscle only and the resistance offered to it, and the problem would be simple enough. It would mean merely the correction of the myopia. But unfortunately we shall see that in compound imbalance at least one other factor—usually several—enter into the problem.

CHAPTER II.

DIVISION III.

ACTUAL INSUFFICIENT ACCOMMODATION.

§ 1. **Definition.**—Actual insufficient accommodation is, as the term indicates, an insufficient action of the ciliary muscle. It is what we have long known as subnormal accommodation or as paresis or paralysis of accommodation. It may be asked why we should not retain that old term, paresis or paralysis?

(*A*) Because actual insufficient accommodation is more definite. It means not simply that the accommodation is subnormal and the difficulty actually in the ciliary muscle itself, but the term is used in contradistinction to relative insufficient accommodation—a condition in which the symptoms are similar but the cause of the insufficiency different.

(*B*) The word "paralysis" should be reserved to express the extreme conditions in which the function of the muscle is nearly or entirely destroyed.

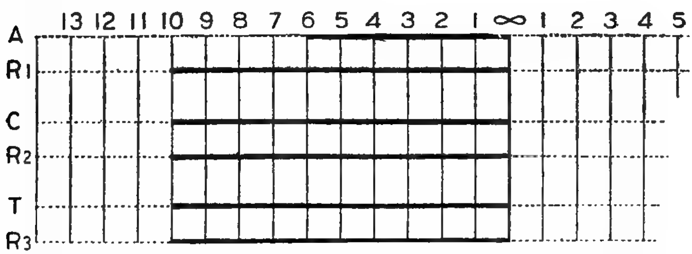

FIG. 10.—Representation of an actual insufficient accommodation of 4. D.

If we represent by diagram the accommodation with the resistance offered to it, in an emmetrope, for example, twenty

years old, in whom there is actual insufficient accommodation of four diopters, we would have a picture such as is represented in Fig. 10. Instead of the usual range of accommodation belonging to a person of that age, we find that it extends from infinity to six diopters only.

§ 2. **Varieties.**—While all cases of actual insufficient accommodation are essentially the same, a very practical difference exists between the form which is due to temporary causes and the chronic variety which results from severe accident or permanent central lesions.

§ 3. **Frequency.**—This condition is quite common, particularly in a slight degree. Long ago Donders observed that "paralysis" of the accommodation was "by no means an unusual occurrence" (B 260, p. 591), and Trousseau and Landolt have called attention not alone to the very evident cases but to those which are more subtle. In this country Theobald (B 897) has written about these slighter forms in which the symptoms are accompanied by what he, with some others, calls subnormal accommodation.

§ 4. **Symptoms.**

(*A*) The near point is abnormally far from the eye in proportion to the age of the subject.

(*B*) The positive part of the relative accommodation is lessened. This is shown even by rough tests with parallel visual axes. We have seen that the normal eye, at least in early life, will overcome —3. D. without difficulty. But the subject of this form of imbalance overcomes only —2.5 D. or —2. D., possibly only —1.5 D.; or, if the paralysis is complete, he cannot overcome any minus glass at all. Moreover, on trial with the convex glasses the negative part of the relative accommodation may be greater than ordinary. Indeed, if we take the time to map out the entire positive part of the relative accommodation, we find that the curve does not rise promptly and fully above the diagonal, but keeps closely to it and crosses it sooner than usual.

(*C*) A minimum dose of atropin sulphate acts in rather a greater degree and in a shorter time than in a normal eye.

(*a*) If a disc containing about 0.00001 gram is applied to the conjunctiva of a person with actual insufficient accom-

modation we see ordinarily that there are not many variations at first in the curve, but that it tends to fall, not

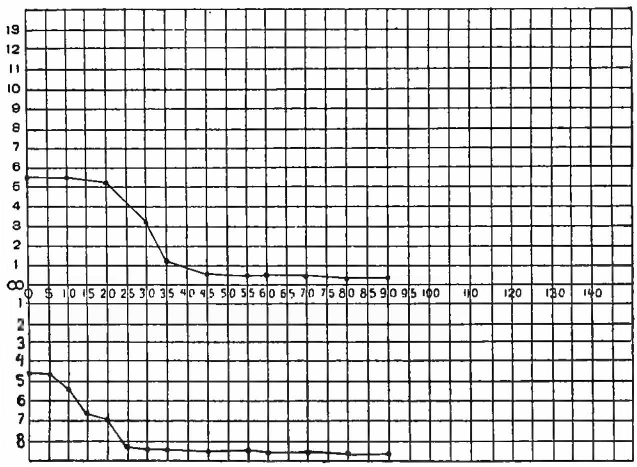

FIG. 11.—Effect of a minimum dose of atropin sulphate in actual insufficient accommodation.

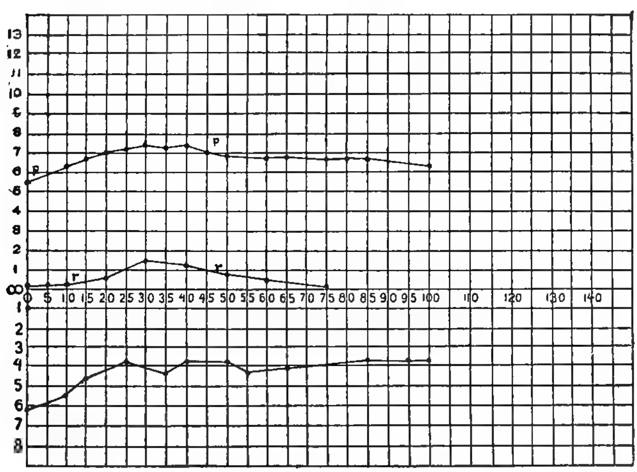

FIG. 12.—Effect of a minimum dose of eserin in actual insufficient accommodation.

necessarily any sooner, but rather more constantly, than

ordinarily with that amount. The effect is more like that of a full dose in the normal eye. (Fig. 11).

(*b*) After the application of a minimum dose of atropin the pupil dilates more promptly than usual, and to a greater extent, but this also is not so constant as to be diagnostic.

(*D*) The effect of a minimum dose of eserin is usually not as prompt nor as complete as in the normal eye. (Fig. 12).

(*a*) If a disc containing 0.00001 gram is placed upon the conjunctiva, the curve obtained is similar to that in the normal eye under the same circumstances, but it is slow in rising, and does not usually attain the height which is reached under similar circumstances in the normal eye.

(*b*) The pupil, after such an application, tends to contract slowly and in a correspondingly slight degree. These effects of minimum doses of eserin cannot be considered diagnostic, but taken in connection with the effects of minimum doses of atropin they furnish strong corroborative evidence.

(*E*) The subjective symptoms which accompany this and the other varieties of insufficient accommodation are numerous and varied. In nearly every one of these cases which is at all marked we have not only the cardinal symptoms of imbalance, but more or less of the additional reflexes. The latter especially are apt to be annoying, the insufficient power of accommodation being often nothing more than the local expression of a general condition. Besides, to repeat once more, discomfort is the rule whenever the positive part of the relative accommodation is less than normal, no matter what the cause may be.

§ 5. **The differential diagnosis** between excessive and insufficient accommodation cannot always be made by means of a single dose of atropin and still less by homatropin. A minimum dose of a cycloplegic or myotic is better when there is sufficient time to use it satisfactorily. But when there is not time for that, or if the usual routine practice is followed, and a full dose of atropin or at least of homatropin is used, then the surgeon is often surprised to see how little effect this produces upon the accommodation.

This is illustrated by a case of hypermetropia like the following.

A young woman comes for relief from headache, and the preliminary trial with glasses shows that she has a manifest hypermetropia of 1.25 D. in each eye. It is necessary for her to return to her home so soon that a proper test with a minimum dose of atropin and of eserin is impracticable. Therefore a full dose of atropin is used at once, and after an hour the tests show that the latent hypermetropia is only 0.25 D., or a total of 1.5 D. The first inference might be that there exists a very weak power of accommodation. But it may also be excessive accommodation that exists. The only way to make the diagnosis is to prolong the use of the cycloplegic. In the case cited, before prescribing any glass, a much safer plan is to give to the patient a full dose of atropin to be applied at short intervals for a week or two. By that time, if there is still as little latent accommodation, we are safe in concluding that we have to do with actual insufficient accommodation; if, however, there is a latent hypermetropia of 0.75 D. or even 1.00 D. the case is, or rather it was, one of excessive accommodation.

§ 6. **The causes** of actual insufficient accommodation are:

(*A*) Local. Among these we have

(*a*) Cycloplegics. As with myotics we can transform a pair of emmetropic eyes into those which present a typical clinical picture of actual excessive accommodation, so by applying to the conjunctiva a suitable dose of atropin we can also produce in that same pair of eyes a condition of actual insufficient accommodation. Therefore this local cause, which is under our control, may be mentioned first, even though the result produced is artificial, and a word is sufficient to call attention to it.

(*b*) Accident. It is a common experience to find that a severe blow upon the eye is followed by effusion of blood into the anterior chamber and mydriasis. Later the blood absorbs, but the pupil remains dilated and the power of accommodation is lost. So after slighter accidents which are soon forgotten, especially by children, the pupil is dilated at first, later it contracts to its normal size, but the complete

power of accommodation is not quite regained. In these examples the condition under consideration usually affects one eye only, but none the less such a cause gives rise to discomfort because of the resulting imbalance.

(*B*) Among the general causes, we have:

(*a*) Diphtheria. When we remember how frequently the bacilli of diphtheria are found in throats otherwise normal, especially during an epidemic, and also that the paralysis may appear long after other symptoms of the disease have disappeared, it seems not unreasonable to ascribe a certain percentage of these cases to diphtheria. Sometimes the insufficient accommodation can be directly traced to this cause. In early youth this may escape observation, but when the near point begins to recede, after sixteen or eighteen, then slighter forms of insufficient accommodation begin to be appreciable.

(*b*) Chlorosis, imperfect elimination, etc. Not infrequently typical cases occur in chlorotic girls and in individuals in whom the nutrition is poor. Sometimes it is associated with even a slight imperfection in the proper elimination of the urea, and in such instances the symptoms improve promptly when the kidneys resume their normal action. In all these cases we should determine as nearly as possible that *ensemble* which we call the general condition of the patient. No such examination can be considered complete until we have ascertained by accurate tests whether any anæmia exists, and its degree, what amount of urea is eliminated in twenty-four hours, with any abnormalities of the kidneys, what is the general muscle strength of the individual expressed in foot-pounds, and other data of a similar kind. Syphilis also should be included in this group of general causes.

(*c*) Finally, this form of imbalance may be hereditary, as is often the case with other abnormalities of the ocular muscles.

A typical example of this hereditary tendency is under observation while these pages are being written, the patients being a mother and two children, each of whom presents an excellent clinical picture of this form of muscle imbalance.

§ 7. **The prognosis** is ordinarily not favorable. In the paresis of diphtheria especially the progress is slow. When one of these cases is recognized, it is safe to give rather a guarded opinion, as to immediate relief at least, and long experience proves that they constitute a class who are a burden to themselves, and likely to be a discredit to the ophthalmologist into whose hands they happen to fall.

§ 8. **The treatment** is often unsatisfactory, although much of course depends on the cause in each individual case. Locally there is not much to be done. Occasionally the persistent use of eserin has been tried, but when any lessening of the symptoms did occur, it was doubtful if that was not dependent as much upon the improvement of the general condition of the individual as upon the drug. As diphtheria is in a certain number of cases either a remote or an immediate cause, it was suggested long ago that the serum therapy might prove of advantage (B 923–926). Its use for that purpose has been advocated by some of the most careful observers, while others have obtained only disappointing results. The general opinion seems to be that in recent cases the serum therapy is of undoubted advantage, but of little or no use in those of long standing. In the latter, nature's own method of treatment seems to be as good as any, although some practitioners may insist upon the virtues of cabinet baths, certain cathartics, or similar treatment. As for other medication, the use of iron is always indicated, but the blood should be tested occasionally to make certain that the form in which it is administered is such as to permit its being taken into the system. Above all, reliance can be placed upon out-door life, such as actual hard work on a farm, or some form of gymnastics. Most persons object to giving up their occupation for life on a farm, and many others are not so situated that they can indulge in golf or similar amusements. What, then, are we to do with those who cannot afford costly forms of exercise? What can we do with the anæmic clerks or seamstresses who crowd the clinics, bringing the same story of headaches which glasses fail to relieve? For them dumb-bells and Indian clubs are undoubtedly of advantage and are inexpensive. The bicycle

has furnished an excellent method of treatment, and has probably cured many a case of insufficiency.

After having observed for some years the result with different plans of exercise, and also the degree in which the average patient will, or rather will not, persist in carrying out the directions given, I am inclined to think that one of the best and simplest methods now at our command is the "universal test for strength." (Vol. I, p. 373.) The patients have been well satisfied with it, and it has served an excellent purpose.

These exercises, as we have seen, give a measure of the strength of the individual when he begins to work, they can be carried out by any one, no expensive apparatus is necessary, the daily measure of strength encourages the patient and also shows the physician how much progress is made. This method will be dealt with again and more in detail in the chapter on compound imbalance.

CHAPTER II.

DIVISION IV.

RELATIVE INSUFFICIENT ACCOMMODATION.

§ 1. **Definition.**—In this condition there is normal action of the ciliary muscle, but an abnormally large amount of resistance offered to it. The result is that the accommodation is unequal to the demands on it, at least for a certain part of its range. This insufficient accommodation is dependent upon, or *relative to*, the resistance offered by the lens. It is by far the most important form of simple imbalance. It includes all cases in which accommodation is impeded or its range restricted, either because the lens is inelastic (presbyopia) or because the globe is too short (hypermetropia), or because, from the position of the lens or from irregular curvature of the cornea, the retinal image is imperfect (astigmatism).

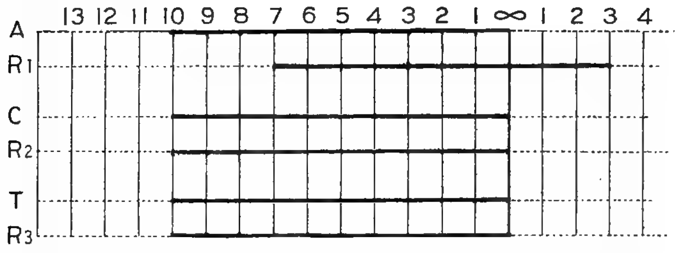

FIG. 13.—Representation of a relative insufficient accommodation (hypermetropia) or hypermetropic astigmatism of 3. D.

Thus in presbyopia parallel rays are focused on the retina without any effort at accommodation until the individual approaches fifty or sixty years of age, but as he cannot accommodate properly we might consider at first that such a case

was more like one of actual insufficient accommodation. It is true it might also for certain reasons be placed in that group, but inasmuch as the inability to focus at a near point is caused by the hardening of the lens rather than by imperfections in the action of the ciliary muscle (although some such imperfection may also exist) it seems more rational to place presbyopia in this group.

As for hypermetropia, there is no question but that these cases, especially in early life, answer to the definition given. The tests which reveal to us the condition of the accommodation show it ordinarily to be normal.

What has been said of hypermetropia holds good evidently of astigmatism when that is of the far-sighted variety. Here still another element comes into account, namely, the effort which the ciliary muscle makes to contract its fibers unequally, though we need not discuss now to what degree that unequal contraction is accomplished in any case.

§ 2. **Frequency.**—As disturbance of accommodation is so often followed by symptoms of eye-strain, and as the varieties of ametropia just mentioned are the most frequent causes of interference with that function, it is evident that this form of muscle imbalance, either in the simple type which is now under consideration, or in the compound type, includes by far the larger number of cases with which we have to deal.

§ 3. **Symptoms.**—As relative insufficient accommodation includes cases in which a normal power of accommodation is unable, without special effort, or without the assistance of a glass, to bring rays to a focus when the eye is adjusted for the near point, evidently an attempt to enumerate its symptoms would necessitate repeating a large part of several chapters from works on refraction. But when we place together the symptoms which accompany these conditions we find there are a few which are common to all, at least in principle, although the details are as varied as the individual cases. Thus we find:

(*A*) The range of accommodation is either normal or its action is limited only by the abnormal resistance offered to

it. This has been already dealt upon and need not be further elaborated.

(*B*) The positive part of the relative accommodation is small and the negative part large. This is simply what we find when we plot the relative accommodation. It is seen, for example, in Fig. 14. Here we have a per-

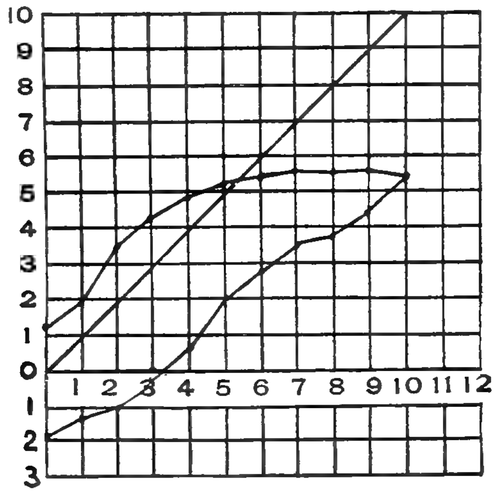

FIG. 14.—Relative accommodation of a hypermetrope.

son with 2. D. of manifest hypermetropia. When he looks at a distant object, − 1.25 D. before each eye is the strongest lens which he can overcome. Therefore in plotting this we count on the first vertical, upward from zero, a distance of one and a quarter squares, and place a mark at that point. But if we place before the eyes of this person a pair of + 2. D. glasses he can also see No. 6 of the test-type distinctly at six meters. That is, with parallel axes the negative part of his relative accommodation is 2. D. Evidently when we plot this we must begin at a point on the first vertical, a distance of two squares below the zero. In a similar manner, with one meter angle of convergence we find he can overcome again − 1. D. and + 2.25 D. These are indicated on the diagram in the manner already explained when considering how to plot

relative accommodation. In a word, the form of the curve or the lines which we obtain by plotting a case of hypermetropia shows that a very large part of the relative accommodation is negative. The curve for a person with hypermetropic astigmatism or with a presbyopia would be of the same character, though of a different form.

The point of importance is that in them the positive part is small as compared with that which is negative. These diagrams are given in most of the larger works on refraction, and others similar to them need not be repeated here.

(*C*) The effects of minimum doses of cycloplegics and myotics in these cases have not been studied with sufficient exactness to warrant very positive statements. It is an interesting field for investigation, but one in which various factors must be taken into account. Such examinations as have been made, however, tend to show that the ciliary muscle in this condition behaves very much as in normal eyes.

(*D*) The subjective symptoms. It is well known, unfortunately, that these are numerous and varied in presbyopia, hypermetropia, and especially in astigmatism. We have not only the cardinal symptoms but reflexes of every kind. With relative insufficient accommodation we know that certain changes occur in the globe, and most of the cases in which the ocular muscles seem to affect different parts of the body are of this kind. Therefore it might be admissible to digress at this point, and consider all of these effects which muscle imbalance has upon the globe. But it is better to hold closely to our line of study. We shall therefore continue with the study of the various anomalies of accommodation and of convergence, and then devote part of a chapter to the effects which the ocular muscles have upon the globe or different parts of the body. That will enable us to deal with all of these various effects of eye-strain as sequelæ rather than as symptoms.

§ 4. **Differential Diagnosis.**—A sharp line of distinction can not always be drawn between actual and relative insufficient accommodation. A good type of each can occasionally be found or produced artificially, but the relative form

often goes gradually into the actual. Thus if we apply to the eyes of an emmetrope a weak dose of a cycloplegic, we produce of course an actual insufficient accommodation. That is quite different from what we find in the eyes of a young hypermetrope whose range of accommodation is normal, and is so large that imperfections in it can be easily detected. In spite of this difference, in certain selected cases, the actual and relative forms of insufficient accommodation do merge into each other by imperceptible degrees. For example, the hypermetrope begins life with a good type of the relative form of this insufficient action, the ciliary muscle in each eye being normal as shown by ordinary tests. If, however, the degree of the hypermetropia is high, or if it is complicated with astigmatism, or certainly after a number of years have elapsed during which this effort to obtain a clear focus has been kept up, then after a time the power of accommodation is no longer normal for a person of his age, but there exists also some actual insufficient accommodation.

§ 5. **Causes** of relative insufficient accommodation:

(*A*) This can be produced artificially in an emmetrope by placing in front of each eye a concave spherical glass. The muscle balance which existed before, changes into imbalance in the form of simple relative insufficient accommodation, its degree being of course in proportion to the strength of the concave spherical glasses.

The usual causes of this condition are:

(*B*) Presbyopia. This is of course the simplest and the most common variety of this form of imbalance. We learned long ago how it is that the ciliary muscle is then incapable of making the lens sufficiently convex and that this lack of the ciliary muscle must be supplied by a glass; it is only necessary therefore to mention this as the most frequent cause of the condition under consideration.

(*C*) Hypermetropia. This cause also is too well known to require elaboration.

(*D*) Astigmatism, especially of the hypermetropic variety.

(*a*) Corneal astigmatism is the variety to which attention is usually directed, probably because the ophthalmometer is

so commonly used. Its importance is by no means to be underestimated, but its frequency and importance are hardly less than of:

(*b*) Lenticular astigmatism, due to irregularities in the structure of the lens (Vol. I, p. 79), or to its malposition (Vol. I, p. 66). This is such an important factor, and is so frequently a cause of imbalance that in the first volume (Chap. II.) much space was devoted to instruments for measuring the existence and degree of any such malposition. In this connection it is only necessary to state, in a general way, that although the slight errors of refraction which are produced by displacement of the lens are usually overcome by the ciliary muscle, especially in early childhood, it is certain that when any such displacement is in a marked degree, although the amount of the astigmatism thus produced may be small, nevertheless, for reasons not well understood, this malposition does give rise to very pronounced symptoms of eye-strain. There are several theories to explain this, but we will not discuss them here.

§ 6. **The treatment** evidently resolves itself into the treatment of presbyopia, hypermetropia, and of astigmatism, particularly of the hypermetropic form. As chapters on these subjects can be found in every work on refraction, we need have as little to do with them in regard to the treatment as we had before when considering them as causes of this form of muscle imbalance. It is proper, however, to call attention to a few underlying principles of treatment:

(*A*) If the discomfort is severe or has lasted a considerable time, a cycloplegic should be used either at the first or at some subsequent visit, in order to determine the refraction accurately.

(*B*) After the refraction has been determined, it should be corrected with the greatest exactness possible.

(C) Gradual increase in the use of eyes (Dyerism). If the discomfort continues after the ametropia has been corrected, and after the ciliary muscle has had opportunity for real rest, or frequently even without any such continuous rest, it is advisable to follow the plan suggested by Dyer. This means to have the patient begin using the eyes for near

work with what is a small amount for that individual, and then increase that each day very gradually, but also as regularly as possible.

In order to determine with what amount the person shall begin using the eyes, it is advisable to make half a dozen or more attempts, and ascertain the average time before some or all of the cardinal symptoms of imbalance are experienced. When this is done, he should begin with an amount rather less than the average. The occupation selected should accord with the tastes or necessities of the individual, and if, as usual, reading is decided upon, the book should have good print and the topic be interesting to the patient.

If it is found that about four or five minutes is the average time which the eyes can be used with comfort for such near work, it is advisable to begin with only two or three minutes, and an addition of one or two minutes a day is quite sufficient. But in that case the patient should make the attempt at least six or eight times during the day, not increasing one or two minutes at each sitting but only one or two minutes each day. If it is possible to use the eyes for fifteen or twenty minutes without discomfort, then a larger number of minutes can be added each day, but the number of attempts can be proportionately lessened. Although this principle is simple, the manner in which it must be worked out in each individual varies greatly. With some, the daily addition must be very small, while with others it can be increased rapidly and satisfactorily. During the earlier stages of this process, especially when the limit is small, care should be taken not to have the patient use the eyes except in the daily exercises prescribed. Later, however, when he can read for one or two hours without difficulty, less caution is necessary in this respect.

It often happens that when the use of the eyes has been gradually increased to forty or fifty minutes, the patient finds to his surprise and disappointment that at a certain sitting it is possible to read only fifteen or twenty minutes before the old discomfort returns. Under such circumstances it is often well to try first to read on in spite of real pain. But if it persists at that sitting, or surely at other trials, it is

better to begin again, starting, for example, with ten or fifteen minutes. In that case, however, the daily increase can be two or three times as large as before the breakdown was reached. When, however, the patient has again reached the limit at which the backward step was taken, he should continue with the daily increment which had been made in reaching that point.

It is by no means certain that the strength of the ocular muscles is actually increased by this gradual increase in the amount of their daily use. In many cases the improvement is apparently due somewhat to the psychological effect—to the confidence perhaps which the patient acquires in the use of the eyes. However that may be, the fact is that the method serves an excellent purpose, and that the results obtained from it are often better than with lenses or prisms or apparatus of any kind.

(D) General treatment. It must suffice at this point to mention that among the factors which constitute the general health and with which we have to do especially, are the condition of the blood, the secretions of the stomach, kidneys, and of course the condition of the nervous system as a whole. The practical bearing of this requires no elaboration.

A remedy which is too often lost sight of is a sufficient quantity of sleep. It is of special advantage when imbalance occurs in neurotic individuals. It is not enough that the patient should have what he considers a sufficient amount, but he should be directed to sleep even ten or eleven hours if possible. If he cannot do that, the mere resting in bed in a semi-conscious condition is of advantage, and probably supplies to a certain extent what the more protracted and inconvenient rest cure does in greater degree.

CHAPTER II.

DIVISION V.

UNEQUAL REFRACTION (ANISOMETROPIA).

§ 1. **Definition.**—Anisometropia is usually defined as a difference in the refraction of the two eyes. This statement, however, is indefinite and has led to some confusion. One practitioner properly understands by it any difference either in the degree of the refraction or in the kind (myopia or hypermetropia). Another understands a difference only in the kind of ametropia. The result is that some writers, appreciating the frequency of anisometropia, consider it of little importance, while others lay great stress upon it. Evidently it would be of advantage to have this definition more specific. We can accomplish this by retaining the term "anisometropia" and having it include, as it does now, all cases in which the refraction in the two eyes is different in any way. Also, it would include emmetropia in one eye and ametropia in the other. Then we could use another term,—for example, antimetropia,—to include those cases in which the ametropia in one eye is the opposite of that in the other. It is better, however, when we have occasion to refer to cases of anisometropia, to specify in plain English whether the unequal refraction is simply a difference in degree or a difference in kind, and also what the amount of that difference is. Theoretically a difference in kind of the refraction may amount to just the same as a difference in degree, but practically the result is not the same.

§ 2. **Frequency.**—Slight differences of refraction are of course very common. It is probable that if each case were carefully tested, under a full dose of a cycloplegic,

we would find anisometropia to be the rule rather than the exception. On the other hand, it is comparatively rare to find opposite forms of ametropia in the same individual.

§ 3. **The symptoms** of the anisometropia vary according to the form of ametropia and consequent imbalance present. In some cases where there is myopia in one eye and hypermetropia in the other, we not only find the objective symptoms of each, but the subjective symptoms also vary according to the condition. Some writers go so far as to say that anisometropia is one of the most constant causes of discomfort.

§ 4. **Treatment.**—This consists essentially in the correction of the ametropia in each eye, according to its kind and degree. It means we should prescribe for each eye the glass which is best adapted for it, no matter if the difference in the ametropia in the two eyes is very slight, or if one eye is normal. The routine fashion of prescribing the same glass for each eye, simply because that is convenient or cheap, cannot be too strongly condemned. On the other hand, it is not always an easy matter to make the two eyes work together, both for distance and for the near point. If there is a difference of more than three or certainly of four diopters, the relative size of the retinal images is so great as to interfere decidedly with comfortable vision. Under such circumstances it requires no small amount of judgment to decide just what amount of correction shall be given to each. Not infrequently it is advisable to disregard entirely the relation of one eye to the other, and give glasses which enable the person to use one eye when looking in the distance and the other for near work.

The general treatment of anisometropia depends upon such principles as have been dealt with already and need not be reviewed here.

SUMMARY OF CHAPTER II.

In this chapter we have studied the anomalies of the intraocular, apart from those of the extraocular, muscles. Such conditions are met with by every practitioner who

does work of this kind carefully. The clinical evidence in this instance was also corroborated by the objective and subjective symptoms furnished by emmetropes before whose eyes convex and concave glasses were placed, and also into whose eyes solutions of eserin, homatropin, and atropin were instilled (foot-note, Vol. I, p. 166). In arranging these data concerning the anomalies of accommodation, we saw in this chapter, first, the two great divisions of abnormal accommodation—on one hand when that was greater, and on the other hand less than normal.

We found that the cases of excessive accommodation can be divided into those in which there is an actual excessive accommodation (that is, a spasm more or less marked), and those cases in which accommodation is not really greater than normal, but only relatively or apparently greater, because the resistance offered to a normal accommodation, by an existing myopia, for example, is less than normal.

In the same way we found that cases of insufficient accommodation can be divided into those in which there is an actual paresis, and those in which the power of accommodation is not actually, but only relatively insufficient, because the resistance offered to a normal power of accommodation by an inelastic lens, or the shortness of the globe, or by some other obstacle is greater than normal. We observed in general that while the treatment of excessive accommodation is comparatively easy, the forms of insufficient accommodation are among the most obstinate conditions with which we have to deal.

CHAPTER III.

SIMPLE IMBALANCE INVOLVING THE EXTRAOCULAR MUSCLES ONLY (SIMPLE HETEROPHORIA).

Having studied the anomalies of the intraocular muscles we now turn to the extraocular. It will be convenient to divide these into groups. Thus, latent deviations caused by the horizontal muscles (anomalies of convergence) will be considered in the first division of this chapter. Those of the oblique muscles (anomalies of torsion) will follow in the second division, these anomalies of convergence and of torsion being intimately connected with anomalies of accommodation. Latent deviations caused by the vertical muscles will be considered in the third division. These are apparently not directly associated with accommodation, though we know very little concerning them, except the existence of certain latent vertical deviations and the asserted existence of others.

A word should be said in regard to the recognition of these forms of heterophoria as a whole, and of their character. Until recently most practitioners have been satisfied to recognize the fact that a heterophoria did exist and to determine its variety and degree. In doing this they supposed that a distinct morbid condition had been recognized, but in reality only a preliminary step in the diagnosis had been taken. In each case we should also ask ourselves whether the eyes tend to turn in, for example, because of excessive action of one or both groups of adductors, or because of insufficient action of one or both groups of abductors. These are the problems now before us.

Again, a word should be said concerning the method of collecting our data. The more closely we study heterophoria the more are we impressed with the fact that four things are

necessary to its proper recognition and to the appreciation of its importance: a thorough knowledge of the anatomy and physiology of the muscles, gained not from books, but from dissections and experiments; the latest and best appliances for making exact measurements; ample time and patience for their use; and an examiner whose mind is free from hampering theories and entirely hospitable to new ideas. It is probable that many who glance through these pages superficially will ridicule the use of complicated instruments or methods to obtain data concerning a subject which is, they think, of comparatively little importance. Such critics should remember that most of our instruments of precision have been regarded as superfluous, at first, and became necessities as our knowledge advanced. Apparently this is to be the history of some of the instruments and methods used for the examination of the ocular muscles.

In the following descriptions of the active and passive varieties of heterophoria or heterotropia, convergent or divergent, it must not be understood that any of these varieties in an *unmixed* type are often met with. For example, with an active form of either esophoria or esotropia we may also have symptoms, more or less marked, of the passive type. Nevertheless, it is desirable to distinguish these different types from each other whenever possible, not for the sake of refinement in diagnosis, but because of the very practical and direct bearing of that difference upon questions of treatment.

A familiar example of two distinct clinical types which also blend more or less is seen in the character of the injection of an inflamed eye. Thus the type of the conjunctival is entirely distinct from that of ciliary injection, yet we do not often find one without some trace of the other. This is not simply a question of diagnosis, but suggests on the one hand astringents and on the other cycloplegics. The difference between active and passive varieties of the different forms of heterophoria is no less important. With these general observations concerning all forms of heterophoria we are better prepared to consider them in detail.

CHAPTER III.

DIVISION I.

LATENT DEVIATIONS PRODUCED BY THE HORIZONTAL MUSCLES.

(ANOMALIES OF CONVERGENCE.)

The anomalies of convergence can be arranged like those of accommodation. Thus an excessive degree of convergence due to abnormal contraction of the interni we could designate simply as an actual excessive convergence, and by elaborating the same general plan with regard to convergence and divergence a similar nomenclature naturally results. While that has the advantage of corresponding with the arrangement adopted for accommodation, the introduction of entirely new terms is always unfortunate. Therefore it is better to express these conditions also in terms of heterophoria. Accordingly our facts relating to abnormal convergence, and therefore divergence, will be arranged in four subdivisions:

Active esophoria (actual excessive convergence).
Passive esophoria (relative excessive convergence).
Active exophoria (relative excessive divergence).
Passive exophoria (actual excessive divergence).

It may seem contradictory to call active esophoria an *actual* excessive convergence, and active exophoria a *relative* excessive divergence. But as a divergence is really a negative convergence, it is more convenient to adopt this classification.

SUBDIVISION I.

Active Esophoria (Actual Excessive Convergence).

§ 1. **Definition.**—Active esophoria or actual excessive convergence is a tendency of the visual axes to turn inward,

caused rather by excessive action of the adductors than by relaxation of the abductors.

A clearer conception of this condition can be obtained by a diagram, even though it is only in outline. In this and in all similar diagrams the line C represents the power of convergence—that is, practically, the action of the adductors. The line R_2 represents the power of divergence, or the resistance to convergence. It is, practically, the action of the abductors seconded by the check ligaments. Fig. 15

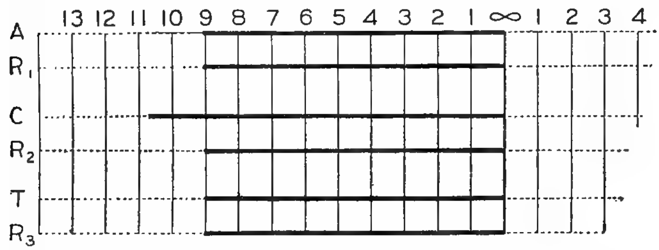

FIG. 15.—Diagrammatic representation of actual excessive convergence (active esophoria).

illustrates the condition in an individual twenty-six years old with an interocular base line of sixty millimeters, who has active esophoria, of one and three-quarter meter angles.

The degree of the excessive convergence is arrived at as follows: when he looks at a test light in the distance we find by the usual methods that there is an esophoria of six degrees. That is, each eye tends to turn in three degrees. Evidently, degrees of convergence cannot be correlated directly with accommodation. If, therefore, we wish to show this form of imbalance by a diagram which shall correspond with diagrams showing imbalance of the intraocular muscles, we must first convert degrees into meter angles. On consulting our table (Vol. I, p. 296) we find that a base line of sixty millimeters with each eye turning in three degrees, corresponds to about one and three-quarter meter angles of convergence. That can be shown by diagram. It means that the line representing convergence must be extended toward the eye one and three-quarter spaces beyond that for the normal accommodation of a person of that age.

It is understood, of course, that this is not an exact calculation, nor is that necessary here. It is only a method of estimating the amount of esophoria in terms of the meter angle, in order to make it comparable with diopters of accommodation, and then representing the result by a diagram.

§ 2. **Frequency.**—While this can be produced by prisms, and while it certainly is met with occasionally in practice, it probably occurs only exceptionally, except when associated with the other forms of imbalance. As a factor in compound muscle imbalance, however, it is one of the very frequent conditions with which we have to deal.

§ 3. **Symptoms.**—(*A*) The objective symptoms of active esophoria are:

(*a*) The tendency of the visual axes to turn inward. The manner of determining the existence of this tendency and its degree, with the sources of error which accompany the tests of various kinds, were discussed when considering the position of both eyes at rest. At present, therefore, it is only necessary to mention this tendency, it being indeed the definition of the condition under consideration. Attention has been called also to the fact that we frequently have in normal eyes this latent convergence for the distance with absence of any such tendency at the near point. This is an apparent contradiction, if we regard orthophoria or any form of heterophoria as separate entities, as has been the habit of late years with some writers. If, however, we consider the physiological fact in its proper relation it is easily explained. It simply means that the visual axes may tend to converge or diverge when the individual looks in the distance—that is, when both accommodation and convergence are relaxed. But when convergence and accommodation are both called into action the relation between the two is more intimate and we have what occurs almost invariably in the normal eye, muscle balance (eukinesis), or as it is improperly called, "orthophoria at the near point." With active esophoria we usually have esophoria not simply for the distance, but at the near point also.

(*b*) The positive part of the relative convergence is in-

creased through at least a part of the distance between the far and the near point. In this condition esophoria is always present with parallel visual axes, that being, indeed, according to our definition. When we place before one eye of the patient a prism, base down, and begin to approach the Graefe dot and line, we find also esophoria at one meter, one half, one third, one fourth, or perhaps the entire distance even to that patient's near point. The degree of this esophoria usually varies, however.

(*c*) The maximum prism convergence is usually large as compared with divergence. This is mentioned simply for completeness, and is not a very reliable indication, unless this large convergence exists not only when the axes are parallel, but also with convergence at one half, one third, or one fourth of a meter. The amount of maximum prism convergence is always variable and easily affected by practice.

(*d*) The ability of the eye to rotate inward is apt to exceed the usual limits, while the ability to rotate outward may remain normal. We have seen (Vol. I, p. 196) that under ordinary circumstances the eye can be turned inward about 40 to 45 degrees; but when there exists an esophoria of any form, the ability to make this inward rotation is apt to be above normal. Evidently we cannot measure it with the perimeter, because of the projection of the nose, but must make use of the tropometer in some one of its forms.

(*e*) The rapidity of the swing inward is increased, at least in certain cases. We would naturally expect this excessive rapidity of the inward movement to occur in every case, but in one patient who was a good type of active esophoria the time of this inward swing seemed to be the same as that outward. This gives us additional evidence, though it can not be considered as diagnostic, and considering the practical difficulties in making these photographic measurements, even with the simplified methods, they can be counted on thus far only as furnishing corroborative evidence. (Vol. I, p. 202.)

(*f*) The lifting power of the adductors is usually greater than normal. In certain cases the adductors can sustain a weight of twenty to thirty grams or even more. This meas-

urement is superfluous, except in rare cases in which it is difficult to arrive at definite conclusions, and in which the severity of the symptoms warrant one in obtaining additional data, even at some inconvenience to the patient.

(*g*) The condition of the general system is sometimes indicative of excessive muscle power, as distinguished from the lack of it. It may be stated in a general way, perhaps, by saying that excess of power is often associated with otherwise perfect health, or plethora, and lack of power is often associated with some form of imperfect nutrition, assimilation or excretion.

(*h*) The position of the head in heterophoria is normal. Some writers state that in certain forms of heterophoria the head assumes a peculiar position; but this is evidently a confusion of a heterophoria with a distinct paralytic heterotropia. These should be kept entirely distinct. It is true that heterophoria passes into heterotropia by imperceptible gradations, and in many cases the underlying cause of all the difficulty is the fact that one muscle or group of muscles has lost a part of its power. But when that insufficiency has reached such a stage that the person is obliged to turn his head in a certain direction in order to avoid the double vision which would otherwise result, by the very act of doing this the malposition of the eye becomes apparent—that is, the heterophoria has passed into a form of heterotropia. As such, it will be considered in another chapter.

(*B*) Subjective symptoms.

From what has been said of physiological esophoria (Vol. I, p. 219) it is not surprising that a considerable excess of convergence can exist in certain individuals without producing discomfort. The reason is undoubtedly analogous to what we find when there is an excess of accommodation. As it is essential to comfortable vision at the working distance that the positive part of the relative accommodation should considerably exceed the negative part, so must the positive part of the relative convergence exceed the negative part. This is of course the case with esophoria. At least, this is probably the basis for the clinical fact that symptoms of discomfort are usually less with esophoria than with

exophoria. It is another way of saying that the work is accomplished more easily because there is a proportionately larger amount of energy available. Yet patients who have the higher degrees of active esophoria, and sometimes only the lower degrees, do come with various complaints. These are usually:

(*a*) The cardinal symptoms of imbalance together with some of the reflexes.

(*b*) A sensation of tension of the adductors. The patients say that they feel as though they were "looking cross-eyed." This symptom is perhaps more frequently met with in actual excessive accommodation, but is also found in active esophoria, and indeed we shall see later that the two conditions are very often associated.

(*c*) Panoramic fatigue. When studying the motions of the eye as it swings from side to side through any considerable arc, we learned what a complicated process that is. It is not surprising, therefore, that when there is any fault in the relation between accommodation and convergence the attempt to look at objects which flit rapidly past the observer should be followed by an unusual amount of fatigue to the eyes. This occurs to many travellers, and has been called the panoramic fatigue. The term expresses the condition met with in convergent imbalance.

§ 4. **The causes** of active esophoria may be of three kinds.

(*A*) Anatomical. To appreciate this we must remember that different internal recti vary in size, as shown by the number of square millimeters which they present on transverse section, and we must also remember how the insertions differ as to position, curvature, and extent (Vol. I, p. 35). In certain instances, one or more of these anatomical peculiarities may be the cause of the excessive energy present. When tenotomy of the internal rectus is made—in certain cases, at least—it is possible actually to see that the insertion of the muscle is abnormal.

(*B*) Physiological. This seems an appropriate term for expressing a set of causes in the production of this variety of excessive convergence, for the reason that these causes

pertain to the physiological relation between accommodation and convergence. By this is meant simply that when the demand upon accommodation is abnormally increased, convergence is increased also. It is with some hesitation that reference is made here to this simple but important fact, for the reason that in doing so we may perhaps confuse the pair of forces which are concerned in convergence (convergence and the resistance to it) with the pair of forces which are concerned in accommodation (accommodation and the resistance to it). That would be to consider here a compound form of imbalance, whereas we are now supposed to deal with the simple forms only. But in reality, active esophoria is so often associated with an effort to accommodate that it would be an omission not to refer to that relation.

With this explanation as a parenthesis, any confusion will be avoided when a little later we consider especially the compound forms of imbalance.

(*C*) Causes affecting the central nervous system. This is a convenient method of expressing our ignorance—unfortunately large—with regard to questions in neurology. That is, causes which we do not know affect the cells in the nerve centres, by some fault of nutrition or elimination, and an ocular imbalance results. Just as a lesion of the brain or spinal cord can produce contractions of the muscles of the forearm, such as we have in writer's cramp, so like causes may produce like effects in the adductors of one eye or both. Some of these causes we are gradually learning, especially results of imperfect assimilation and of imperfect elimination, with other conditions which tend to interfere in one way or another with the normal action of the nervous system.

§ 5. **Treatment.**—The question arises first, whether any treatment at all is advisable, so long as the patient is comfortable. In answer to this we may say, most certainly no. But when the individual does suffer from discomfort and proper correction of any ametropia has been made, we may then ask ourselves what can be done for this excessive muscle action. If we proceed by the classic route of treatment and attempt to remove the causes, we find ourselves confronted

first by the question whether there are any anatomical reasons in a given case to produce this result, and if so, how they can be obviated. That suggests methods of changing these anatomical conditions,—in other words, operation,—a phase of the entire subject which we shall discuss last of all.

But if the individual suffers at the same time from hysteria, chorea, or other difficulties of the nervous system or other parts of the body, is it permissible to make a patient of such an individual, on the supposition that these difficulties are dependent upon the eye? To this also a negative reply must of course be given. In such a case we should make only a provisional diagnosis, and have the correction of the imbalance as complete as possible without giving unnecessary anxiety or inconvenience.

CHAPTER III.

DIVISION I.

SUBDIVISION II.

Passive Esophoria (Relative Excessive Convergence).

§ 1. **Definition.**—Passive esophoria (relative excessive convergence) is a condition in which the visual axes tend to turn inward, not because of an excessive action of the adductors, but from lack of resistance offered to them by the abductors. This is usually in the nature of paresis of the sixth nerve on one side or both, although not to such a degree as to deserve that term as ordinarily used. The insufficiency, however, may also depend on other abductors, namely, the obliques (Vol. I, p. 188). A better idea can be obtained of this condition also if we represent it by diagram. Let us suppose that we have an individual with normal power of convergence, but with a resistance to that convergence rather less than usual. If we approximate the amount, expressing it in meter angles as before, we can represent it as in the accompanying diagram (Fig. 16).

§ 2. **The frequency** of this variety is probably by no means as great as that of the active form, although the data on this point are comparatively few. The reason is that we

are only beginning to separate our cases of esophoria into two classes. Even now, as the points in differential diagnosis are few, and require patience, suitable appliances, and some skill to work them out accurately, too many practitioners are content to ignore them. Hence positive statements as to the relative frequency of the active as compared with the passive variety of esophoria must be made with caution.

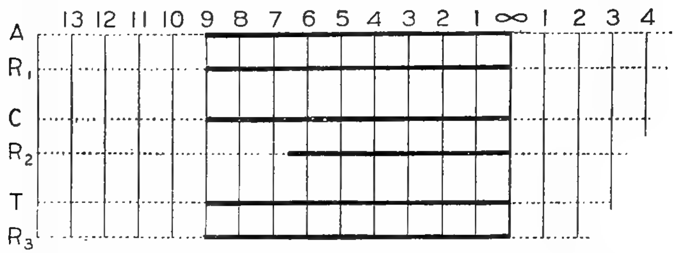

FIG. 16.—Diagrammatic representation of passive esophoria (relative excessive convergence).

§ 3. **The symptoms** of passive esophoria are very similar to those of the active form, and several of them might be rehearsed almost in the same order. It is only necessary therefore to call attention to those modifications of the symptoms which particularly distinguish the passive from the active form of esophoria.

Thus we find (*A*) among the objective signs:

(*a*) The field of fixation outward is usually restricted. In the active form, as we have seen, the excursion outward does not differ materially from that of the normal eye, either as regards the limit to which the visual axes can be turned, or as to the behavior of the eye in attempting to make that excursion. In the typical passive form, however, this is different. If, after the eye has been properly centered and the head firmly fixed, we measure the excursion outward with a perimeter, either by the objective or the subjective method, and especially if the vision is such that the latter method can be made to verify the former, we find that the ability of one eye or both to turn outward is distinctly limited. In some cases, when the objective method is used, if we look over the sight points to observe the reflection of

the electric light in the pupil, we find that the globe will advance as far as 30 or 35 degrees, but there it comes to a halt. Occasionally, if we urge the patient sharply, directing him to turn the eye still farther out and out, the limit of this excursion may reach 40, 45, or perhaps a greater number of degrees, but that position can be held only for an instant. Moreover, the behavior of the globe in attempting to make that movement is quite characteristic. It does not turn to a certain point and remain there, but as it approaches the outer limit of its range it vacillates, as it were, in its attempt to reach the extreme point, and then gives up the effort. Or again, if the experiment is repeated after a few minutes, we find that the outer limit which was reached before cannot be attained a second time, or if it is, the position is not held with nearly the degree of steadiness manifested at the earlier trials. In other words, the abductors are, as it were, fatigued.

(*b*) The limit of excursion inward as shown by the tropometer exceeds the normal—that is, the total range from the inner to the outer limits is of about the usual number of degrees, but the swing outward is more or less limited. It will be noticed that the field of fixation differs from that which the active form gives.

(*c*) The maximum power of prism convergence with parallel visual axes is apt to be excessive as compared with prism divergence. This is the same as in the active form, but in a more marked degree.

(*d*) The positive part of the relative convergence, although in general larger than normal, is often irregular in amount at different points and also at different times. In the active variety this increase is especially noticeable in the vicinity of the near point, where, as usual, accommodation and convergence are more nearly allied than when the axes are parallel. Moreover, in the active variety the line representing the positive part of the relative convergence is quite regular, and varies comparatively little with repeated tests. In the passive variety this line is irregular. Thus in the latter, we may find an esophoria of three degrees when tested with the distant light. This may increase to four degrees at two meter angles, to none at three meter angles, and

so on with decided variations. It seems more rational to account for these fluctuations by insufficient action of the abductors, especially when we take into account what may be called the steadying effect of combined action of accommodation and convergence.

(*e*) The maximum power of prism convergence is usually large as compared with divergence. In this it does not differ at all from the active form.

(*f*) The period of rest after an inward swing is apparently increased. This may prove an interesting point in differentiating the passive from the active forms. In several of these photographic tracings of cases in which the power of the abductors was less than normal, as the globe swung inward, the period of rest at that point was considerably longer than after its swing outward. This was particularly well marked in one of the photograms, although it may have been only an individual peculiarity.

(*B*) The subjective symptoms are similar to those already described under the active form, though "the feeling of looking cross-eyed" which is noticed with the active form is perhaps not so frequent.

§. 4. **The differential diagnosis** between active and passive esophoria is often difficult, and sometimes practically impossible. It is for this reason that the symptoms have been given in some detail, and attention has been called to the differences between the two varieties. An unmixed type of either is comparatively rare. Even if a case is of the passive variety early in life, it may approach the active form later, or the reverse, one of these merging into the other. Nevertheless, it is desirable to keep these two types of esophoria clearly before us, for although the symptoms may be at first confusing, yet when worked out carefully, and the preponderant type recognized, that diagnosis is important, and the treatment more intelligent.

§. 5. **Causes.**—(*A*) Among these are probably causes which we may call anatomical. Yet of them we know comparatively little. It is true that in cases of esotropia of long standing the external rectus has been found decidedly less developed proportionately than the internal, but it still re-

mains for exact post-mortem examinations to be made of the length and size of the lateral recti in cases of heterophoria.

(*B*) Passive esophoria is produced by causes which affect the central nervous system. We all see plenty of cases which we recognize at once as "paralysis" of the abductors, which are due to what we call immediately "a central lesion." In proportion as we look carefully for them we also see a considerable proportion of cases of "paresis" of that group, which we also ascribe to "a central lesion." So if we look still more carefully, not hastily and with insufficient methods, but patiently and with the aid of recent and exact appliances, we discover these cases in a still earlier stage or slighter degree. These we recognize as examples of passive esophoria, and consider some of them also due to "a central lesion."

Thus we know that syphilis is one of the most frequent causes of what we ordinarily term paralysis of the sixth nerve. The usual extreme case is recognized without difficulty and considered simply a routine affair. But we are apt to overlook the other cases in which the cause is the same and the lesion the same, but in so slight a degree as not to produce what we call a "paralysis," or even what we call a "paresis." The cases of slight infection do fall, however, into the group now under discussion, and some of them present almost typical clinical pictures of passive esophoria, or of passive exophoria if the third nerve is affected.

§ 6. **Treatment.**—First of all, it should be remembered that esophoria of either type does not ordinarily produce such marked discomfort as does the corresponding degree of exophoria. Therefore, in very many cases, passive esophoria does not demand any treatment at all. Where that is necessary, however, the same general plan is indicated as in the treatment of passive exophoria. As this latter is so much more common than passive esophoria, and as practically all which would be said of the condition now under consideration applies also with proper modifications to passive exophoria, it is more convenient, and tends to clearness, to leave the treatment of passive esophoria, with all questions of muscle exercise, to be dealt with when we come to the treatment of the former condition.

CHAPTER III.

DIVISION I.

SUBDIVISION III.

Active Exophoria (Relative Insufficient Convergence).

§ 1. **Definition.**—In active exophoria (relative insufficient convergence) there is a tendency of the visual axes to diverge, due principally to excessive action of the abductors on one or both sides. This can also be represented by diagram with sufficient exactness to give a clearer idea of the condition. Let us suppose that the patient has an interocular base line of 58 millimeters and an exophoria of four degrees, or latent divergence of two degrees for each eye (Fig. 17).

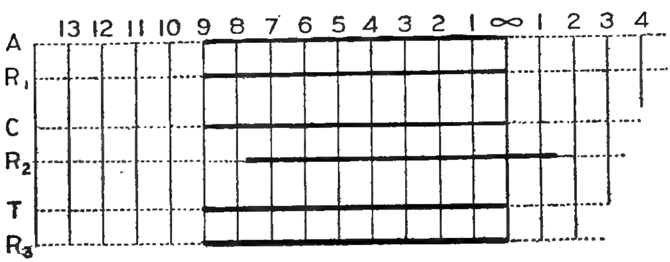

FIG. 17.—Diagrammatic representation of relative insufficient convergence (active exophoria).

As degrees cannot be expressed in terms of accommodation until they are converted into meter angles, an apparent difficulty arises, because our patient does not tend to converge at all, but, instead, tends to diverge. That does not interfere, however, with the estimate, for it was long ago shown by Nagel and Landolt (B 328, p. 341) that divergence is simply negative convergence. We may therefore proceed on the same plan as before; that is, on consulting our table (Vol. I, p. 296) we find that a base line of 58 millimeters, and each eye turning out, for example, two degrees, corresponds to 1.2 meter angles of negative convergence. Active

*es*ophoria was called also actual excessive convergence, but an active *ex*ophoria is not properly an actual excessive divergence, if, as just stated, we are to consider divergence as negative convergence.

§ 2. **Frequency.**—This is a rare condition. In nearly all cases of divergence, either latent or apparent, the cause is some imperfect action of the adductors. There are occasionally cases, however, in which the action of the abductors is excessive. At least, the usual tests lead to this conclusion.

§ 3. **Symptoms.**—(*A*) Objectively:

(*a*) The tendency of the visual axes is to turn outward as given in our definition.

(*b*) The relative convergence is decreased through at least a part of the distance between the far and the near point. If we follow the usual plan of placing a prism of about eight degrees with the base down before one eye, and then approach the Graefe line and dot to one meter, one half, one third, etc., we find that the deviation does not tend to decrease as the near point is reached, as in esophoria. On the other hand, the exophoria tends to increase.

(*c*) The maximum prism convergence is usually small as compared with divergence. This is a corollary of the last proposition, although its existence and degree are not of great importance, because so easily influenced by practice and by other factors.

(*d*) There is a tendency to divergence when an object is gradually brought near the eyes. If the point of a pencil is gradually approached in the median line, we find not only that divergence occurs, as has already been found by the test for relative convergence with the Graefe line and dot, but that not infrequently when we reach a certain point the tendency to diverge remains, in repeated tests, much *more marked in one eye* than the other.

(*e*) The ability of the eye to rotate outward is apt to exceed considerably the normal limit, while the ability to rotate inward may be *nearly or quite normal.*

(*f*) The rapidity of the outward swing appears at least as great as that of the inward swing. Most of the photographic measurements made of normal eyes by Dodge (B 469) or

by Mr. Duschak and myself, indicate that the swing inward is decidedly more rapid than the swing outward. When, therefore, we find that these two are the same, it is in accordance with what we would expect with exophoria of this variety. The point is stated with some caution, simply because of the paucity of the data at our command.

(*B*) Subjective symptoms. Here we have the cardinal symptoms of eye-strain with reflexes, unusually abundant and of various kinds. The reason is promptly suggested when we recall the physiological fact, so often referred to, that for comfortable binocular vision at the working distance the positive part of the relative accommodation and also of the relative convergence must be proportionately larger than the negative part, whereas with exophoria of either variety the negative part is abnormally large.

§. 4. **The causes** of active exophoria, like those of the opposite type, may be of three kinds. These are not only suggested by the three causes of active esophoria, but are so entirely analogous that it is unnecessary to enter into detail concerning them.

§. 5. **Treatment.**—(*A*) Local. We have seen that in the treatment of the imbalance produced by an excess of accommodation or of convergence the principal reliance was placed on rest in some form. When dealing, as we are now, with an excess in the power of divergence, we might at first imagine that here again rest was indicated. But as divergence is only negative convergence, evidently in order to obviate the imbalance our first effort should be toward strengthening the convergence.

We shall not discuss at this point the forms of muscle exercise or their relative values, but merely refer to the principle of treatment involved in active exophoria.

The problem in such a case is how to make the adductors, and indirectly the ciliary muscle *stronger than normal*, in order to balance the excessive power of abduction. That is not easy to accomplish, A gymnast can develop the muscles of his arm, it is true, beyond the normal, but it is done with some difficulty and only to a limited degree.

Is it desirable to prescribe weak abductive prisms, thus

resting one or both externi? Undoubtedly some temporary relief from the discomfort can usually be obtained in that way, but when such a plan is continued too long it ultimately makes a bad matter worse. Every ophthalmologist who has observed his cases closely can recall instances of that kind. In active exophoria, therefore, if exercise of the interni is so unreliable, and if abductive prisms are worse than useless, what then remains to us in the form of local treatment? Evidently not much. But it is in this form of exophoria that advancement is warrantable. Fortunately such cases are rare.

Besides, considerable improvement at least can often be obtained through general treatment. But when it is a choice between constant discomfort and perhaps loss of occupation on the one hand, and, on the other, an operation which is entirely safe if cautiously done, the latter is to be preferred. Its technique will be considered later.

(*B*) General treatment. The utmost care must be taken to improve the general health as much as possible. Imperfect digestion, mental over-work or worry should of course be eliminated, tests should be made of the condition of the stomach and of the kidneys, especially the amount of urea excreted, of the percentage of hæmoglobin in the blood, and last, but not least, of the general muscle strength in foot-pounds. Some or all of these data usually point to a cause which guides the general treatment. By carrying this out, especially by improving the hygienic surroundings and habits of the patient, improvement usually begins and often renders any thought of operation unnecessary.

As good types of active exophoria are rare, it might seem unnecessary to give so much attention to their treatment. But cases which approach that type are not infrequently met with. and to these of course, as to the passive form of exophoria, these suggestions about the general treatment also apply.

CHAPTER III.

DIVISION I.

SUBDIVISION IV.

Passive Exophoria (Actual Insufficient Convergence).

§ 1. **Definition.**—In passive exophoria (actual insufficient convergence) the visual axes tend to diverge because of insufficient action of the adductors. Fig. 18 illustrates roughly this condition. The usual tests have shown a total exophoria of six degrees, or three degrees for each eye. As the base line in this individual is 55 millimeters, by converting three degrees into meter angles by our table (Vol. I, p. 296) we find it corresponds to a negative convergence of 1.9 or practically two meter angles. This is shown in the diagram by the line C.

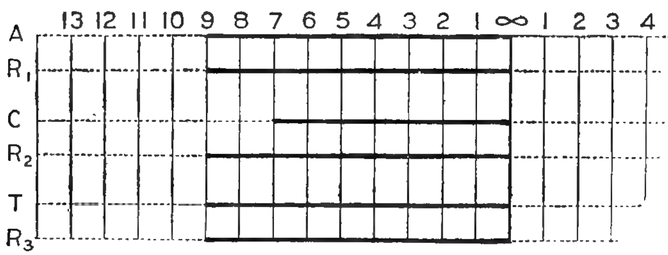

FIG. 18.—**Actual Insufficient Convergence.**

§ 2. **Frequency.**—Next to relative insufficient accommodation, passive exophoria is the most frequent form of simple imbalance. At least, it is the form which most frequently attracts attention, not only from the annoying character of the symptoms but also because of the obstinacy with which they persist.

§ 3. **The symptoms** objectively are:

(*A*) Those which we find in the active form of exophoria. Much which has been said concerning the latter applies with equal force to the passive variety. Therefore instead of repeating these it is better to point out how the passive form of exophoria differs from the active.

It must be admitted that in many cases a differential diagnosis is impossible. It should also be borne in mind that one of these forms merges into the other, sometimes by imperceptible gradations. The first four symptoms referred to in connection with the active type are also found in the passive. But in the differential diagnosis much depends on:

(*a*) The limits of the field of fixation. To determine this a suitable perimeter or tropometer, or both, is an absolute necessity. Moreover, the measurements must be made patiently, carefully, and repeatedly. If that is done, the extent of the outward swing in the passive type will be found excessive, as it is also in the active type.

But in the passive type there is a limited excursion inward. The tropometer also shows that when the globe turns in to a certain point, although we may order the patient, sharply and emphatically, to turn the eye farther, it remains about at that limit. In active exophoria, on the contrary, when the eye turns inward to the apparent limit, the patient, if urged suddenly, can rotate it a few degrees still farther inward. This may appear rather doubtful evidence on which to base a differential diagnosis between active and passive exophoria, and yet, in some cases at least, there can be no question of the validity of this conclusion.

(*b*) Finally, the lifting power of the adductors has appeared to be lessened in a few cases of the passive type which have been measured, but on this point also we need more accurate data.

(*c*) The rapidity and extent of the swing outward compared with the swing inward, as shown by photograms, may also throw some light on the differential diagnosis of the two types. In these tests, of course, the other eye is closed.

(*B*) Subjective symptoms. It is in this class of cases, more than in any other, or perhaps more than in all others combined, that we find abundant and varied forms of eye-strain. This is a common experience. Every practitioner knows when he recognizes an exophoria—especially if it is due to insufficient action of the adductors—that he may expect complaints from the patient at the first visit, and will

be fortunate if he does not hear the same complaints at a number of subsequent visits.

It is unnecessary to pass all these different symptoms in review. Suffice it to say, that in this group we find the cardinal symptoms practically always present, and the more common reflexes almost invariably develop at some time or other, unless the imbalance is corrected before it has reached a very marked degree. It may be mentioned at this point, however, that in some cases of compound imbalance there is a considerable degree of exophoria, and when this exophoria is not a primary condition, but only secondary to insufficient accommodation, the exophoria in itself gives little or no inconvenience.

These ocular symptoms and the reflexes resulting from the imbalance should not be confused with another and a very important group of symptoms which is sometimes present, and which depends primarily upon the condition of the general system. Their existence is a decided help in arriving at a diagnosis. Among these should be classed the paralyses, however slight, in another portion of the body. Sometimes we have only an imperfect knee-jerk, but very frequently there exists an anæmia or other general condition of like character, which may be considered by some as a result of the ocular condition, and by others a cause of it. However that may be, the co-existence of these conditions is of importance, not only for diagnosis, but also, of course, in determining the treatment.

§ 4. **The causes** are the three with which we are familiar.

(*A*) Anatomical. These are well illustrated by the result which every operator has unfortunately obtained when he has over-corrected an esotropia. He has simply altered the anatomical relation of the muscle, and a typical passive exophoria, if not an exotropia, has resulted. Such an example needs no comment to show that there may be an anatomical basis for these various forms of convergent imbalance, which in this example affects the adductors, and in others like it affects other muscles. When the imbalance is produced by operation we can watch the process as it

goes on before us, though evidently such opportunities are not eagerly sought by the surgeon and are still less welcome to the patient.

Or anatomical causes of actual insufficient convergence may exist in the muscles themselves. Although we know from dissections that there are great differences in the muscles, especially in the position and the extent of their attachments, we do not know in any individual case that these anatomical peculiarities of structure produce corresponding peculiarities of action. We do know, however, from the cases collected by Starr of New York (B 127) and others, that certain branches of the third nerve are often defective while other branches are perfectly normal. Indeed, the more carefully we study cases of slight paralysis, the more frequently do we find those in which only some of the branches of the third nerve are affected. It would be easy to build up theories to account for this—to say, for example, that the group of cells in the nucleus of the third nerve which supplies fibers going to this or to that muscle were affected, while other fibers in that nucleus remain intact (Vol. I, p. 97). While this is probable, we do well to avoid theorizing and continue our efforts to arrange the facts.

(*B*) Physiological causes. These are so nearly analogous to those in relative insufficient accommodation, that, *mutatis mutandis*, nothing more need be said concerning them.

(*C*) Other causes dependent upon mal-assimilation or nutrition or disturbances of the nervous system are of importance, but it is unnecessary to enter into detail concerning them either, as enough has already been said in regard to the changes upon which they depend.

§ 5. The **prognosis** in passive exophoria depends of course upon the cause of the difficulty and its degree. When due to excessive tenotomy the error can usually be corrected by advancement.

In cases which are dependent upon or at least accompanied by anæmia, by imperfect elimination of urea, or certain dyscrasias improvement is perhaps the rule.

The most obstinate cases are those in which the lack of

sufficient tone exists in other groups of muscles also, and in which there are evidences of central lesions. Ordinarily, when these exist, the degenerative changes are such that a favorable outcome of the eye difficulty is not to be expected, unless this lesion be of an acute character.

§ 6. **Treatment.**—From our ignorance of these ultimate causes it is evident that we have yet much to learn concerning the local treatment. Still, there are certain principles which may serve as a guide in the general plan to be pursued. They indicate that the adductors should be trained, if possible, to do their accustomed work.

First, exercise of the ocular muscles. This is perhaps the most natural point at which to consider the effect of exercise upon the extraocular muscles, not because it is suited to this form of imbalance alone, or even more to this than to some other forms, but because in the professional mind this exercise is usually associated with exophoria.

The different forms of muscle exercise are:

(*A*) Wall to wall exercise.
(*B*) Strong prisms occasionally, for distant objects.
(*C*) Strong prisms (not stereoscopic) occasionally, for near objects.
(*D*) The refracting stereoscope.
(*E*) The reflecting stereoscope.
(*F*) Weak prisms constantly.

(*A*) Exercise simply by moving the eyes from the extreme limit of fixation on one side to the extreme limit on the other has been called the wall-to-wall exercise. It has some strong advocates. If any one will take the trouble to turn his own eyes thus to the extreme limit right and left, not simply a few times, but for a few minutes, he will appreciate by the fatigue produced that the method is not without some effect, whatever that may be. But it is an inconvenient performance, especially if it must be frequently repeated. Theoretically it has the disadvantage of exercising the adductors just as much as it does the abductors, thus maintaining the same proportionate strength as before. Practically the plan has not proved of sufficient clinical value to keep it in general use.

(*B*) Strong prisms *occasionally*, for *distant* objects. If some artificial method is necessary for exercise of the ocular muscles we think first of prisms. No one wishes to wear these all the time, and two different methods have been suggested with the hope of obviating such a necessity. The first plan is to use strong prisms occasionally when viewing a distant object. This has been called the back-and-forward prism exercise. For example, when it is desired to exercise the adductors, a prism with the base out, as strong as the patient can conveniently use, is

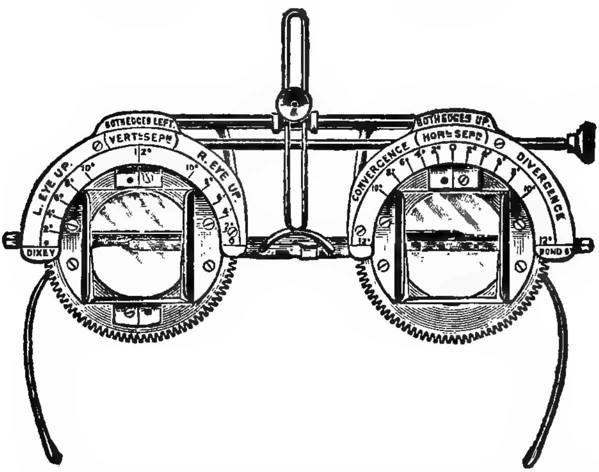

FIG. 19.—Arrangement of prisms by Maddox for testing heterophoria, and also convenient for occasional muscle exercises.

placed before each eye in frames similar to those already described (Vol. I, p. 283). In this connection, however, mention should be made of the prism frames recently devised by Maddox (Fig. 19). Although this arrangement is intended primarily for uses similar to those of the Stevens phorometer (Vol. I., p. 229), yet when the prisms are mounted in this way they serve also for exercising occasionally the horizontal or indeed any other group of muscles. Whatever frames are selected, when adductive prisms are used, the patient is placed before a test light about half a meter distant in order that he may easily fuse the retinal images. He is then

directed to walk backward from the light, meanwhile retaining the single vision as long as possible. In this way we find that at first diplopia may be apparent after he has taken one or two steps backward, but by persisting, he will be able to recede farther and farther, thus increasing his power of convergence. For exercise of the abductors, of course the position of the prisms must be reversed, and the patient gradually approaches the light. These occasional exercises with prisms are sometimes a little complicated, they take up the time of the individual, and what is especially a disadvantage with neurotic patients, the treatment keeps the attention of the invalid fixed upon the difficulty, thus causing its importance to be exaggerated.

(*C*) Use of strong prisms (not stereoscopic) *occasionally*,

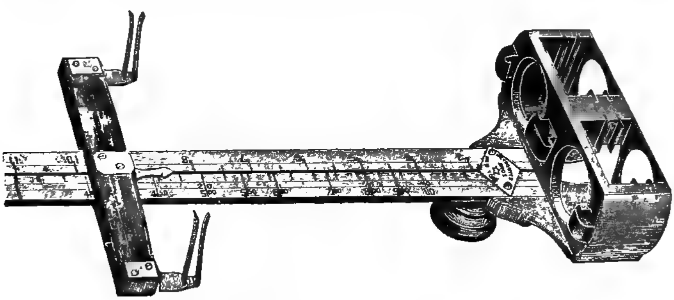

FIG. 20.—Noyes' stereoscope.

for *near* objects. These are worn some minutes or a few hours when the person is attempting near work. Of course they affect the convergence only, making that greater than it would be normally for the distance at which the object is held while the accommodation for that point remains undisturbed. It should be observed that the prisms arranged in this way have an effect slightly different from those of the stereoscope. In the latter the convergence is increased while the accommodation is diminished, and moreover, with the latter there is a fusion of two different images. Although these strong adductive prisms for occasional use are quite frequently prescribed, it is doubtful if they are of special value. The fact that they are cumbersome and that their use demands

special time and attention tends to class them with forms of exercise having comparatively few advantages in proportion to the disadvantages.

(*D*) The refracting stereoscope. When studying the fourth group of associated movements of the normal eye, we saw how different forms of the stereoscopes affected both accommodation and convergence or convergence alone.

Let us turn again to the refracting stereoscope. This has been used by different ophthalmologists and has undergone various modifications, but Brewster's idea still remains. The principal objects of these modifications are:

(*a*) To permit easy changes in the glasses or to lengthen the central bar so as to place the pictures at a considerable distance (Noyes, Fig. 20).

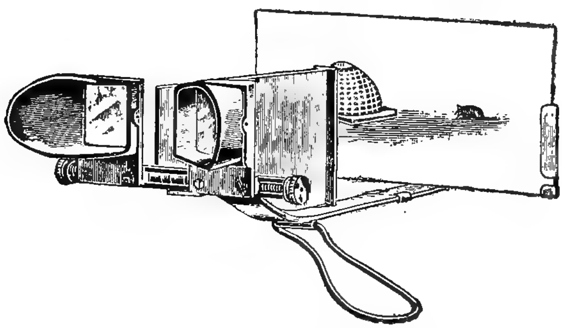

FIG. 21.—Stereoscope of Knoll.

(*b*) To make the pictures of such a form that they serve as a measure of the completeness of the stereoscopic vision obtained (Derby; the author, Vol. I., pp. 307–308), and as a source of amusement to hold the attention of children while the muscles are being exercised (Knoll, Fig. 21).

(*c*) To lighten and simplify the mechanism.

(*E*) The reflecting stereoscope. Javal was one of the first to call attention to the clinical value of this form of the stereoscope, arranging the mirrors also as Wheatstone did (Vol. I, p. 305), but inclining them to each other on hinges. Comparatively little notice was taken of the reflecting stereoscope, and some of the text-books pass this form over with hardly more than mention. But very recently attention was

called to the principle again, and notably through the simple and clever arrangement of the pictures by Worth. Still more recently this tubular form of the reflecting stereoscope has been improved and modified by Black, and at present constitutes the most attractive method of stereoscopic muscle exercise.

But no matter which form of the stereoscope is selected we should rate it only at its real value for the purpose for which it is then employed. While these later modifications of the instrument are invaluable for the development of *fusion* in an amblyopic eye, on the other hand, when considered as a means of accomplishing ocular muscle *exercise* they are more cumbersome and sometimes no more useful than weak prisms or decentered lenses worn constantly. But when objections are made to glasses, the stereoscope furnishes the next best method, apparently, of exercising the ocular muscles.

(*F*) The constant use of weak prisms. These may be in the form of eye-glasses or spectacles, or the prismatic effect may be obtained by decentering a glass ordinarily worn. The principle involved has already been dwelt upon at some length (Vol. I, p. 291). This is the form in which prisms are usually prescribed, and as their value is often underrated by the surgeon who is not careful in his directions, and as they are apt to be discarded by the patient as inconvenient or altogether unsatisfactory, it is essential to keep in mind a few fundamental facts concerning their use.

We naturally ask first in what position they are to be placed, whether so as to favor the affected muscles or group of muscles or so as to give them more exercise. This question has brought forth no small amount of discussion, apparently because an exact diagnosis of the deviation has not been made, nor the distinction between an excessive and an insufficient action of a muscle or group of muscles. Such a diagnosis is not always possible, but when it is, the indications for the use of prisms are much simplified. In considering them here it may be understood that reference to "a muscle" may mean in this connection an entire group of muscles.

It will be generally agreed that indications for this treatment are:

First, to relieve the patient, if only temporarily, from the annoying symptoms. This can be accomplished usually, at least in part, by placing the base of the prism toward an insufficient group of muscles, and the apex toward a group whose action is excessive. We say this arrangement tends to give rest, and we know in practice that when this can be accomplished, ordinarily some relief is noticeable.

A second indication is to give more permanent relief. This aspect of the question may be divided into two parts.

(*a*) How should a prism be placed when the action of the affected muscles is excessive? Experience seems to show that in some of these cases the most relief is experienced when the prism is placed with the apex toward the affected muscle. In other words, it is kept in the same position as at first prescribed. Indeed, it may be desirable to make its effect even greater than at first.

(*b*) When we have to deal with an insufficient action, the problem is quite different. In that case the prism which is prescribed temporarily should be as weak as possible and worn as little as possible. In a case of passive exophoria, for example, an abductive prism at first gives relief, but the ultimate object is not to favor the abductors too much, but to strengthen the adductors. Naturally we would suppose that under such circumstances an abductive prism used even temporarily would be a disadvantage, and that is true in certain cases. But as far as we know anything about this obscure subject, it is probable that the condition is similar to that which occurs with weakened muscles in any other part of the body. The first indication is to give relief temporarily, by a bandage or otherwise, and then later to strengthen the affected muscles by systematic and gradually increasing exercise. This rule probably applies to muscles of the eye when their action is insufficient. This is why Dyerism or various forms of prism exercise are often beneficial. We have the prisms, we know how they act, but we do not know as yet, with a given degree of insufficiency, how much the insufficient muscle should be favored, and how much it should be exercised. These details must be determined by the elements which enter into each individual case.

Also much depends on the strength of the prisms and on changes made in them.

(*c*) The prisms should always be made a little too weak rather than too strong. This necessitates frequent changes, it is true, but much less inconvenience is given to the patient, and the result is certainly apt to be better than with a decided change at any one time. The natural objection to the expense can also be obviated, as in several American cities, at least, the opticians are accustomed to rent prisms in frames at a nominal sum per month, expecting the patient to make as many changes as desired.

(*d*) Increase in the strength of the prisms should not be rapid. Even though the patient is quite accustomed to a certain strength, it is better to wait too long than too short a time, before we proceed to the next in the series.

(*e*) Sometimes the strength of the prism must be decreased or the prism must be removed, or even another worn which has an opposite effect. In a word, the constant use of weak prisms requires no small amount of care and study of the individual case, but with persistence and with patience in the measurements made from time to time, it is certainly possible to prescribe prisms much more intelligently than is ordinarily done. They are not to be discarded simply because with a few trials they prove unsatisfactory, or because extravagant claims of the miracles wrought with them cannot be made good. Within certain limits they are of really great clinical value.

General treatment. All that has been said previously concerning the necessity of careful and patient search for general causes with a view to intelligent treatment holds especially true for this form of muscle imbalance. Therefore it might be considered only necessary here to call attention to the fact that the passive type of exophoria is most common among the anæmic and poorly-nourished, and to leave the subject at that point. But it would be an omission not to lay stress upon the great advantage which these patients can derive from some gymnastic exercise.

CHAPTER III.

DIVISION II.

LATENT DEVIATIONS PRODUCED BY THE OBLIQUE MUSCLES.

(ANOMALIES OF TORSION).

§ 1. Cyclophoria has already been defined (Vol. I, p. 220) as the tendency of one or both vertical axes to revolve in or out about the antero-posterior axis. We have learned (Vol. I, p. 244) what the tests for cyclophoria are, and how the measurements are made. Our attention has also been called to the fact that if, when looking through a clinoscope or a tortometer, the vertical lines are rotated too far inward or outward to permit prompt fusion, and are held at that point, after a time a feeling of discomfort can be perceived, as distinct as if a prism had been placed before each eye. It is evident that in any such case there is a muscle imbalance.

The question now before us, therefore, concerns the nature of this effort of the obliques; or rather, it is what anomalies of torsion produce the different symptoms. These questions tempt us to follow the same plan which we did with regard to accommodation and convergence—that is, to recognize an active and a passive form of ex- and of intorsion, but the facts thus far at our command do not warrant such subdivisions. Our physiological data are unfortunately few, and still less numerous are accurate measurements of pathological conditions of this kind. It should be remembered also that practically torsion is difficult to measure and its variations are so small as not always to be reliable. But in spite of these difficulties, it is possible to recognize, at least with a fair degree of confidence, what may be called an excessive and an insufficient form of torsion. We will now consider these.

CHAPTER III.

DIVISION II.

SUBDIVISION I.

Excessive Torsion.

§ 1. **Definition.**—In excessive torsion, as the term indicates, the upper end of the vertical axis tends to turn or does turn farther outward than normal. It is possible to represent this approximately by a diagram similar to the one used to illustrate the imbalance due to anomalies of accommodation or of convergence. For example, if a person with normal eyes, and with base line of 61 *mm.*, accommodates and converges for a point one-fourth of a meter distant in the horizontal plane, he also converges 7° (Vol. I, p. 294), and under normal conditions the upper end of the vertical axis tips outward about 2° 05′ (Vol. I, p. 360). But suppose in a given case, with such a base line and such an amount of convergence, the upper end of the vertical axis is found to tip outward not 2° 05′ but 2° 30′.

According to the table last mentioned, an outward tipping of 2° 30′ is such as accompanies ordinarily a convergence of ten degrees. But according to the first table (Vol. I, p. 294), when a person who has a base line of 61 *mm.* converges ten degrees, that corresponds to between five and six meter angles—that is, the excessive tipping is such as corresponds to the difference between four and about five and a half, or rather more than one and a half, meter angles of convergence. Such a condition can be shown by diagram (Fig. 22).

It should be understood again that this is only an approximation in order to show how such a diagram can be constructed in order to obtain a clearer mental image of the condition before us. The fact is, that these rotations of the globe vary somewhat from time to time, and although it is possible in a laboratory to measure the amount of torsion quite exactly, as Landolt did, when these measurements are made clinically they are approximate, and can be relied upon only by taking the average of different observations.

§ 2. **Frequency.**—This muscular anomaly seems to be rather rare, but perhaps that is only because exact measurements of it are comparatively few. If we study this class of cases more accurately, especially in their relation to astigmatism, we may find they are more frequent and also more important than is usually supposed.

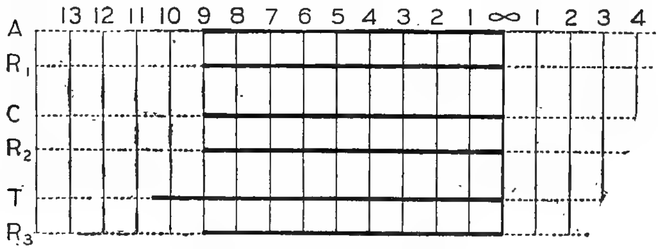

FIG. 22.—Excessive torsion.

§ 3. The **symptoms** of excessive torsion as revealed by appropriate tests, or those which we have called

(*A*) Objective symptoms, are:

(*a*) The Maddox prism may show that there is some extorsion (Vol. I, p. 245) even with parallel visual axes.

(*b*) The clinoscope shows that both the minimum and maximum extorsion are rather large as compared with the intorsion (Vol. I, p. 263). When we measure the extorsion which is found with convergence in the horizontal plane, or in planes above or below it, the tortometer shows rather more than the normal amount of tipping outward. Sometimes these different tests reveal the same tendency of the torsion, but in different degrees; or else excessive torsion may be found to exist with parallel axes and not with convergence, or the reverse. The reason for this is not understood.

(*B*) The subjective symptoms are usually the cardinal ones of imbalance, but various reflexes also are often present. In as much as we know by experiment that even a small change in the degree of torsion is usually accompanied by decided discomfort, we would expect *a priori* that when, for any reason, a torsion does exist, it would give rise to the more common reflexes.

§ 4. **Causes** of excessive torsion. The classification of

causes which has been adopted in regard to faults of convergence suggests that a similar arrangement might be followed in regard to torsion, but of these we know almost nothing. There is one condition, however, partly anatomical and partly physiological, which may cause one eye or both to rotate on the antero-posterior diameter to a greater or less amount than normal. That is the presence of a considerable degree of astigmatism. Let us suppose that in the right eye we have an astigmatism of such a nature that a vertical line in the distance is brought to a focus only when the upper end of the vertical axis is inclined five degrees out. Let us suppose also that in the left eye there is also an astigmatism of such a nature that a line in the distance can be brought to a focus only when the upper end of the vertical axis of that eye is inclined fifteen degrees out. Whenever such a person attempts to look at any vertical lines as, for example, at windows, doors, pictures, etc., evidently as long as the two eyes are in the primary position and without any torsion, neither of them would see these distant lines distinctly. It would be possible, however, for the two images of the line to be fused if a corresponding extorsion were to take place in each eye. It makes no difference of course in what direction the axes of astigmatism may be; the effect is the same, although more noticeable in some positions than in others. This idea of the clinical relation of torsion to astigmatism has been elaborated to a considerable extent and perhaps with undue emphasis by one or two writers. At first we probably were all inclined to consider the whole subject as too hypothetical to warrant much consideration (B 462–612), but further study has led some students, at least, to the conclusion that a condition somewhat analogous to this is indeed the cause of the torsional imbalance which exists in certain individuals, and that it produces the most annoying and obstinate symptoms with which we have to deal.

§ 5. **Treatment.**—From what has been said of the causes of excessive torsion it is evident that in considering the treatment our attention is turned first to the position in which to place the axes of the glasses in order to correct any existing astigmatism. The importance of this can hardly be over-

estimated. Although we learned long ago to recognize astigmatism by various methods and to correct it accurately according to optical standards, we have not taken into account sufficiently the relation which the axis of the astigmatism bears to this important function, torsion. When we test our patients with the radiating lines at a distance of six meters, we determine in that way the axis of the astigmatism, when the vertical axes of the eyes are either practically vertical or as they converge downward to meet at a very small angle. It is true that the astigmatic glass which gives the best vision under such circumstances is usually also the one best adapted for reading, because there is little or no torsion when we look at an object thirty or forty degrees below the horizontal plane. But if that person has an occupation which requires him to look at near objects in the horizontal plane, or if he must look often at objects above that plane—then the astigmatic glasses which were prescribed from tests made with the eyes in the primary position do not properly correct the astigmatism. The difficulty with the cylinders is that the axes are placed too nearly vertical. This point has been already referred to (Vol. I. p. 365).

At first glance, this may seem to be a refinement of measurement which is entirely unnecessary. For most cases that is perfectly true. As most persons can wear without much inconvenience a spherical glass which theoretically is not quite of the proper strength, so we find in practice that for the vast majority of persons the oblique muscles can correct a considerable amount of torsion without producing the least discomfort. But as very accurate correction of an ametropia is necessary in some individuals, so does the position of the axes of the astigmatism make a decided difference to others. Of that there is ample clinical evidence. In a word, therefore, for persons whose occupation requires them to look directly in front, or above, it is better to tip the axes a few degrees farther out than is apparently necessary with tests made at a distance of six meters.

Is it possible to improve an excess of torsion by exercise of the oblique muscles? Perhaps that might be done, in a case of astigmatism, by a correction which tends to tip the

upper end of the axis of one eye or both a little too far toward the median plane. Indeed, that plan has been suggested, but thus far the results obtained have been of rather doubtful value. It is a field of study in which accurate measurements and careful observations are much to be desired.

CHAPTER III.

DIVISION II.

SUBDIVISION II.

Insufficient Torsion.

In insufficient torsion the upper end of the vertical axis does not tend to turn outward as far as it should normally. This is of course the opposite of excessive torsion. What has just been said therefore concerning the latter holds true also, with

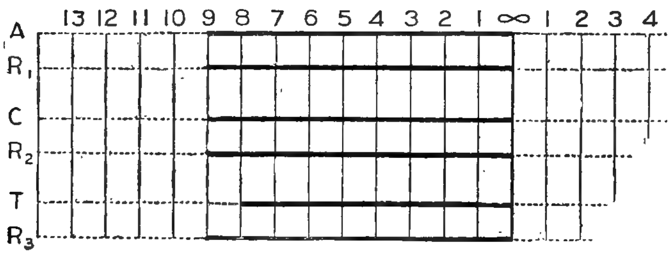

FIG. 23.—Insufficient torsion.

proper changes, of the former. Thus a diagrammatic representation may be made of this condition in a manner analogous to that for excessive torsion. Although such a representation cannot be considered exact, nevertheless it gives us a mental picture of this pathological condition. Fig. 23 is a representation of an insufficient torsion equivalent in amount to one meter angle of convergence and therefore to one diopter of accommodation.

It is unnecessary to repeat here what has been said in the last subdivision, since it applies also, with proper modifications, to insufficient torsion.

CHAPTER III.

DIVISION III.

LATENT DEVIATIONS PRODUCED BY THE VERTICAL MUSCLES.

(ELEVATIONS AND DECLINATIONS .

SUBDIVISION I.

Hyperphoria and Hypophoria.

Thus far we have attempted to arrange and examine anomalies of accommodation, of convergence, and of torsion. These were considered first because we know quite definitely the relation of each, under normal conditions, to the act of comfortable vision at the near point. But we do not know what relation, if any, the vertical muscles bear directly to that act. We do know, however, that when muscle imbalance is produced artificially, by placing a vertical prism before one eye or both, or when such an imbalance is produced by disease, we have the cardinal symptoms of imbalance usually manifested and also at least the more common reflexes. We therefore enquire now what these forms of vertical imbalance are and their clinical importance. It will save repetition if we consider first hyperphoria, and then simply compare hypophoria with that.

§ 1. **Definition.**—Hyperphoria is, as we have learned, a tendency of one eye to turn above the horizontal plane while the other fixes a distant object immediately in front. The different tests for this, their relative value, and the sources of error in making the measurements need not be repeated.

§ 2. **Frequency.**—Different observers have, apparently, arrived at different conclusions on this point. Thus Posey states (B 1060) that at least thirteen per cent. of all patients suffer from hyperphoria, though when such measurements are

made upon healthy subjects, as was done by Bannister and others (Vol. I, p. 241), it appears that the vertical deviations even with them constitute about ten per cent.

§ 3. **Symptoms.**—(*A*) The objective symptoms.

(*a*) A tendency of one eye to turn upward. This is in accord with the definition given and the statement needs no elaboration.

(*b*) The tropometer shows that the field of fixation upward is rather larger than in the normal condition. When this measurement is made with any of the tropometers (Vol. I, p. 193), we find also that the upward motion is more steady near the limit of upward rotation than in the downward motion. It must be remembered, however, that these results with the tropometer alone, especially with measurements on the vertical muscles, are reliable only after repeated verification.

(*B*) **Subjective Symptoms.**—These are of rather an indefinite character and are often the same as the cardinal symptoms of muscle imbalance. We are apt to have in addition a considerable number of the reflexes, their number and intensity varying much in different individuals.

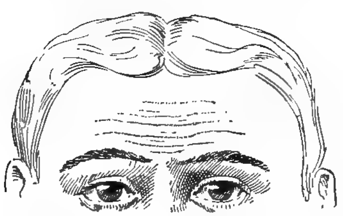

FIG. 24.—Horizontal wrinkles on the forehead produced by hyperphoria.

Among the symptoms of hyperphoria there is perhaps none more characteristic than the wrinkling of the skin of the forehead. It is true that this occasionally occurs in persons who have no perceptible vertical imbalance, and also that most persons, as they grow old, acquire these horizontal wrinkles upon the forehead. But it is certain that in a very considerable number of cases of vertical deviations, whether there is a hyperphoria of one eye or of both (an anophoria),

there is a tendency to the formation of horizontal lines across the forehead such as we see in Fig. 24. In some cases this is noticeable even in early childhood. Without much doubt in such a case the anterior vertical fibers of the occipito-frontalis act as accessory muscles.

§ 4. **Differential Diagnosis.**—It is easy enough to recognize with the Maddox rod or other tests that one eye tends to turn up while the other fixes the distant object. But to make a definite diagnosis between hyperphoria on one side and hypophoria on the other is quite a different matter. Several authors, especially of American text-books, speak of this in an off-hand fashion, leaving it to be inferred that one form can always be distinguished from the other. The truth is that if the left eye fixes and the right tends to turn upward,—for example, three degrees,—then when the right eye fixes the other will tend to turn downward practically the same amount. It is true that in a certain small percentage of cases, when we use the tropometer, the arc of excursion upward on one side seems to differ slightly from the downward excursion on the other side. In the vast majority such a difference in the motion cannot be recognized, and one must be honest in saying that this differential diagnosis is not possible. Fortunately, however, in the matter of treatment that is of slight importance.

§ 5. **Causes.**—(*A*) Anatomical. As far as can be ascertained, no dissections have thus far been made to determine the relative size of the vertical muscles in cases of hyperphoria or hypophoria. Nor is it easy to obtain many data even as to the insertions of these muscles, since we have occasion to operate on them so infrequently. It is well known, however, that congenital peculiarities do exist in the orbits, of such a nature as to make it probable that corresponding peculiarities exist in the vertical muscles themselves. This is especially true as far as asymmetry is concerned. The vertical asymmetry of the face is noticed by any one who has used the tropometer in any form, or sometimes it can be noticed with the ophthalmometer. When the tangent scale (Vol. I, p. 195) of the former instrument is turned vertically, in order to measure the field of fixation above or below, on revolving

the tube on its vertical stand to the other eye, we find in a very large majority of cases that the eyes are not on the same horizontal plane. In many persons the facial asymmetry can be seen simply by holding a card horizontally below the eyes. This is an important fact. That difference in the position of the eyes is sometimes rectified by tipping the entire head to one side or the other, but, whether that occurs or not, it is evident that the asymmetry would tend to the increased development of one or another part of the vertical muscles.

(*B*) Physiological causes. That these exist there can be no doubt. If we place a vertical prism before either eye, just strong enough not to produce diplopia, a sufficient amount of imbalance is produced to give discomfort, and this discomfort is usually increased in proportion to the amount of effort made in accommodation and convergence. In other words, the condition of the vertical muscles apparently bears some relation to the three familiar primary factors. But when we go a step farther and ask just what that relation is, we are obliged to confess our ignorance. In a given case of right hyperphoria, for example, we do not know whether that upward deviation is of an active or a passive nature, or even whether the deviation is merely secondary to some abnormality in the vertical muscles of the other eye.

§ 6. **Treatment.**—(*A*) Local. This consists principally in the use of prisms. But it must be admitted that the manner of using them is entirely empirical, inasmuch as we have no means of determining even approximately the *nature* of a given hyperphoria—that is, as we do not know whether this tendency of the eye to turn up is dependent on undue contraction of the levators or on relaxation of the depressors. Evidently, therefore, we must be content in cases of hyperphoria to place the prism or prisms in the position which gives the greatest amount of relief, even temporarily. That is, when we have a right hyperphoria, we prescribe a prism before the right with the base down, or divide the effect with another prism in the opposite direction before the left.

(*B*) Constitutional treatment. What has been said on this point concerning other forms of heterophoria need not be repeated. As we find frequently that anæmia or various toxæmias tend to aggravate this condition, the same indications exist for tonics and out-of-door life. With these, again, the advantage of exercise is not to be overlooked, and still again mention should be made of the gymnastics suggested by Sargent.

(*C*) Operative treatment. This is to be considered only as a last resort. One or two text-books on the ocular muscles have certainly done no little harm by advocating operation for hyperphoria and hypophoria when there is apparently but slight provocation for it. Aside from all other questions, a reason against operation on the vertical muscles is that they are so much more difficult to reach than those in the horizontal plane. Tenotomies and advancements are difficult enough to do exactly, and therefore properly, when the operative field is large and the desired corrections are also large. But still greater difficulties are encountered when the field is small and the finer gradations of results are required, than when only the phorias exist. A surgeon who might decide promptly to operate for any form of heterotropia would hesitate long before attacking a hyperphoria or hypophoria, even in the rare cases in which it seems perhaps advisable. And yet, in spite of that, we find such operations made constantly by those who really believe that these vertical deviations are the causes of many reflexes, but who have not studied the general condition of their patients with any special care.

Hypophoria. From what has been said of the differential diagnosis between hyperphoria of one eye and hypophoria of the other it is evident that the two conditions are so related to each other that it is useless to treat each separately. All that has been said of the former holds with equal force, *mutatis mutandis*, of the latter.

CHAPTER III.

DIVISION III.

SUBDIVISION II.

Anophoria and Katophoria.

1. **Definition**—Anophoria has been defined as a tendency of both eyes to turn upward. While it is easy enough to form a mental picture of such a condition, it is by no means so easy to establish its existence by reliable measurement.

§ 2. **Frequency.**—If we were to judge of the frequency of this condition by the space devoted to its consideration in some text-books, we would naturally suppose that such cases are very often met with. It is true that cases answering that description are seen once in a great while, especially in conjunction with other imperfections of the ocular muscles. Just in the same way we meet occasionally with typical examples of double ptosis. If we admit with Posey that some latent vertical deviation occurs in about thirteen per cent. "of all cases of refraction," then hyperphoria is probably not more than half as frequent, and anophoria certainly still more rare.

§ 3. **The Symptoms** usually described are :

(*a*) An excess of the upward, with or without a restriction or imperfection of the downward movement of both eyes. In a certain small percentage of cases repeated measurement with the tropometer indicates that there really is some limitation vertically of the normal field of fixation. But their number is exceedingly small and they have not yet been studied with the care which perhaps they deserve. But it is certain that their importance is often much over-estimated, and many of the statements in regard to the necessity of dividing muscles to correct any such anomaly cannot be too strongly condemned.

(*b*) A supposed symptom of anophoria, and one on which Stevens lays much stress (B 573, p. 317), is the tendency to lower the chin and raise the eyes.

It is true that such a pose of the head is occasionally seen,

especially in children. But in two such cases at least, in which the pose was typically that described for anophoria, careful measurements with the tropometer failed to show the least excess of rotation upward or imperfection of rotation downward.

The importance of this habit of tipping the head forward has been much over-estimated. For example, Stevens says (B 573, p. 25): "Is it not easy to see that the position of the head causes the upper air passages to shut like a valve? The hinge is at the larynx. Not all such persons suffer the full penalty for this restriction in the act of respiration, but too many do.

"If we visit one of the modern hospitals for consumptives, the most striking thing to a close observer will be this prevailing pose of the head, and this mechanical obstruction of the larynx. . . ."

It is unfortunate that a writer who has done so much for this branch of ophthalmology should indulge in statements which have apparently no clinical evidence to support them. A word of protest must therefore be entered against the asserted importance of this symptom of anophoria, lest the whole subject be dismissed as unworthy of serious consideration.

§ 4. **The causes** of anophoria are quite unknown, though they are probably the same as those which produce paresis of other branches of the third nerve. It should be observed, however, that the tipping forward of the head which is ascribed to anophoria is in many cases hereditary or due to lack of training. We find occasionally two or three members of a family who have a tendency to bring the head forward, and a stooping posture is often the result of simple carelessness on the part of the parent or teacher in allowing a child to bend over his desk in an ungainly attitude.

§ 5. **Treatment.**—It is evident that in the very rare cases where the tropometer does show an increase in the upward field of fixation and a decrease in the downward part of the field in both eyes, our only way is to place a prism before each eye base down. Although this is an empirical method, it is about all that can be done.

But in the cases that are sent to us simply because of a

suspicion of such an anomaly of the ocular muscles we should say frankly that what the patient needs is something of the setting-up process of a military school. He should be compelled to carry his head on his shoulders in the way nature intended, and not allow it to lop forward out of place. Such advice is not always pleasantly received, but it is certainly the best for the patient; it is also less expensive than operations for correction of an imaginary "elevation."

Katophoria.—After what has been said of anophoria it would evidently be useless repetition to discuss in detail the opposite condition. It is only necessary to call attention to the fallacy of supposing that because a person holds the head erect or perhaps slightly thrown back, therefore some rare and strange condition of the vertical ocular muscles exists. We only need to recall again the influence of heredity and occupation. Just as we notice that a peculiar manner of walking or of carrying the shoulders is hereditary, so is also the position of the head. The erect posture, with the head thrown somewhat backward, is not uncommon among people who are accustomed to balance burdens on their heads. This is seen from the fishwives of Scotland to the peasants of southern Europe. The negroes in our southern States are accustomed to carry baskets and heavy weights on the head, and in their efforts to maintain the center of gravity they develop an erect carriage, almost of the military type. If we were to judge the condition of the ocular muscles by the position of the head, nearly every man and woman in a Southern market-place would be considered a typical case of katophoria. It is worthy of note that in Stevens' description of katophoria (B 573, Fig. 109) he uses the head of a negro to illustrate the peculiar pose.

SUMMARY OF CHAPTER III.

Having dealt in the second chapter with forms of simple imbalance which are produced by the intraocular muscles, we considered in the third chapter the forms of simple imbalance produced by the extraocular muscles. In order to do this, the extraocular muscles were divided into groups accord-

ing to their well-known functions. Thus, one group contained those acting in the horizontal plane (relating to convergence), another group included the oblique muscles (relating to torsion), while the third or the vertical group included those which related to elevation or depression of the visual axes. Each of these groups was considered also according to the nature of the action of the muscles, following the same general plan as when dealing with anomalies of accommodation to such an extent as clinical facts seemed to warrant. That is, if the action of a group of muscles was found to be abnormal, then as it must be either greater or less than normal, there were two aspects of that abnormal action to be considered—excessive or insufficient action. Finally, each of these forms of excessive or insufficient action might be divided into one form of action which was actually excessive or actually insufficient, and another form which was only relatively excessive or relatively insufficient. For example, the abnormal action of the horizontal muscle was recognized as a tendency to turn inward (esophoria), and a tendency to turn outward (exophoria), just as we have always done. But an effort was made to go a step farther. The esophoria was divided into an active form—that is, when the eye tends to turn inward because of excessive action of the adductors,—and a passive form, when the eye tends to turn inward because of relaxation of the abductors. Although it was impossible always to distinguish between these two conditions, and although they frequently merged into each other by imperceptible gradations, still it was found that a working basis for such a classification does exist, and is moreover of decided practical value as far as the horizontal muscles are concerned. While our ignorance of the oblique muscles makes it impossible to carry such a classification into any detail, a brief statement was made as to what we do, or rather do not know concerning their anomalies. We also inquired concerning anomalies of the vertical muscles, and saw the difficulty or impossibility of diagnosing certain conditions of those muscles. In other words, in this chapter we have endeavored to arrange the different varieties of simple imbalance of the extraocular muscles, and to study each one by itself.

CHAPTER IV.

COMPOUND IMBALANCE.

ANOMALIES OF TWO OR MORE GROUPS OF MUSCLES.

COMPOUND HETEROCYKINESIS AND HETEROPHORIA.

HAVING studied thus the different forms of simple imbalance, we are better prepared to understand cases in which two or more of these forms of simple imbalance are present in the same pair of eyes. This chapter therefore will be devoted to compound imbalance. But it will not be possible to follow here exactly the same plan which we have adopted with regard to the different forms of simple imbalance. As clearness is essential in dealing with a complex subject like this, and as the plan here pursued is quite different from that followed by previous students, it is desirable thus at the outset to indicate the path which is to be followed, and then at the end to review the salient points.

In the first division of this chapter we shall consider what the different forms of compound imbalance are.

In the second division we shall study the effects which the ocular muscles have, either on the eye itself, on adjacent parts, on the nervous system especially, and on other portions of the body.

Another division deals with those subjective symptoms of imbalance, or forms of actual imbalance, which are apparently not the result of any condition in the eyes themselves, but are reflexes from abnormal conditions elsewhere.

The last division will be devoted to questions of treatment which relate to all forms of imbalance, and to the importance of basing the general treatment on the result of accurate medical examinations. The fact is also emphasized that if the ophthalmologist fulfils thus his duties as a physician, his sphere of work is obviously quite different from that of the optician.

CHAPTER IV.

DIVISION I.

VARIETIES OF COMPOUND IMBALANCE AND THE PRINCIPLES INVOLVED IN THEIR TREATMENT.

§ 1. The **definition** of compound imbalance has been already given. It was also stated that there are two varieties of this, the associated and the dissociated. In the former, we find that the principal factors in the problem (accommodation, convergence, and torsion) are affected in about the same manner, though not always to the same degree. In the latter, they seem to bear no special relation to each other. This has been dwelt upon sufficiently.

When studying the simple forms of imbalance, we called the force, or the effort which was made by a muscle or group of muscles to produce a given effect, the principal factor or element of that form of simple imbalance, and the resistance which was offered to that force a secondary factor or element. —Vol. I., p. 367.

But these terms need not be limited to muscular action or the resistance offered to it. It can include morbid conditions which constitute distinct ultimate causes. Thus an anæmia, or a toxæmia, may constitute an element in a given case.

§ 2. **Frequency.**—Most of the cases of imbalance with which we have to do in practice are those of the compound form. When we remember that this means all anomalies of the muscles, and also all the anomalies of refraction, we appreciate how large this class is. As a disturbance of a single one of the three pairs of factors is apt to disturb also the relation of one or more of the other factors, we may have, apparently, as many different forms of compound imbalance as

there are permutations of six. Moreover, the vertical muscles may add their quota to the list, and the number be further increased almost indefinitely because of the degree which each primary or each secondary factor may vary from the normal. Such variations in the conditions of the ocular muscles give rise to an almost infinite variety of clinical pictures, each one modified by what we call the general health of the individual. In a word, we have all the different conditions which are met with day after day and year after year. Such a conclusion is not only astonishing, but at first glance it is disheartening, except for those who delight in theoretical and impossible difficulties in the study of the muscles.

Fortunately, however, in the question of treatment the problem is not so complicated. For, as in algebra, an equation often contains factors which cancel each other, so in a certain way factors of muscle imbalance may be eliminated by the fundamental rule of associated action. This means, in a word, that when we correct the principal abnormal element, the others which are associated with it tend to correct themselves.

§ 3. **Symptoms.**—When considering these we should remember that compound imbalance is not a disease, but only the name of two or more abnormal muscular conditions each of which is by itself distinct from the other. If therefore we ask what are the symptoms of this condition the question may mean:

What different forms of simple imbalance usually do combine or may combine to produce types of compound imbalance? or else:

What sensations are usually experienced or may be experienced either as symptoms or as sequelæ of such a combination? At present we shall consider the first aspect of the question, leaving the strictly subjective phases to be treated not as symptoms but as sequelæ, in subsequent divisions of this chapter.

Let us observe first how similar forms of simple imbalance unite to produce an associated compound type. One, for example, may be called the excessive or spastic type. In this we find not infrequently some actual excessive accom-

modation and an esophoria; and sometimes an excess of torsion. This combination of the different elements which enter into vision we frequently find among those whose eyes have been taxed by near work, especially under imperfect illumination. (Fig. 25.)

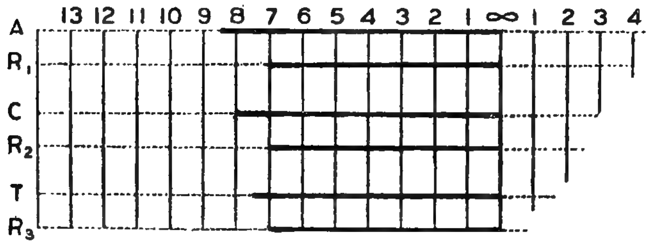

FIG. 25.—Associated compound imbalance of the excessive or spastic type. The excessive accommodation is the most important element.

Another type of cases of the excessive or spastic type of accommodation is presented roughly in Fig. 26. In these

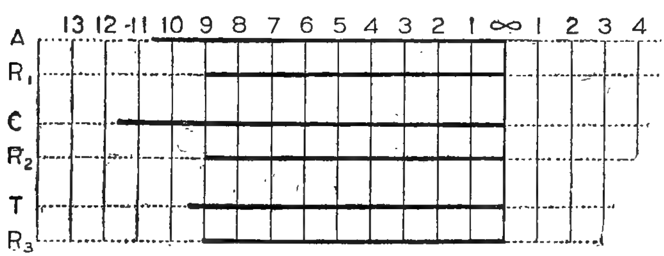

FIG. 26.—Associated compound imbalance of the excessive or spastic type in which the excessive convergence is the most important element.

the degree of esophoria is considerably greater than the excessive accommodation. In other words, the excessive convergence is at once recognized as the important element.

Another form of the associated compound imbalance is of the insufficient type. We find insufficient accommodation, nearly always insufficient convergence, and the torsion is apt to be abnormal, though not always insufficient. This is seen in Fig. 27.

It must be remembered, however, that while we often find accommodation and convergence both affected in the same

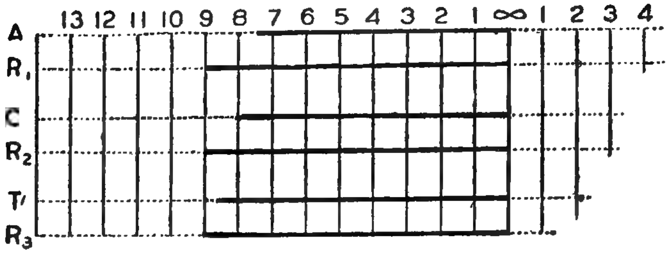

FIG. 27.—Associated compound imbalance of the insufficient type in which the insufficient accommodation is the most important element.

way, if the torsion is affected at all it may be in the opposite manner. Such a case is represented in Fig. 28. In this

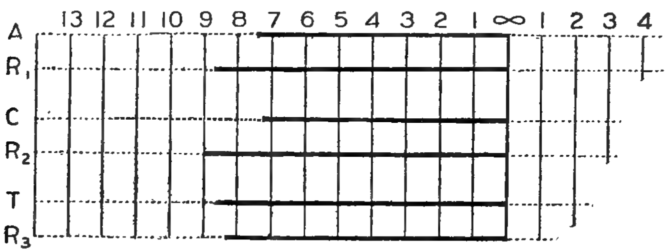

FIG. 28.—Associated compound imbalance; the insufficient form not entirely of the associated type.

there is insufficient accommodation and insufficient convergence, but a slight excess of torsion. Such a case of course is not strictly an associated imbalance, though it approaches that type.

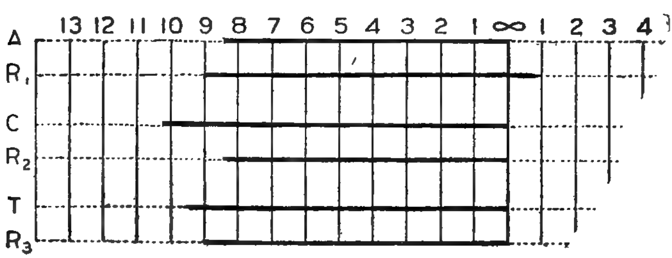

FIG. 29.—Dissociated compound imbalance.

Finally, dissociated compound imbalance is not infrequent. An example of such a case is seen in Fig. 29. In

this the different factors bear no relation to each other, and in their treatment we strive to correct each element as best we can.

§ 3. **Diagnosis.**—As we are now dealing with cases such as are met with every day, the practitioner of experience may protest that he already has his method of arriving at a diagnosis, which has served him well perhaps for many years. Such methods are often as good as any one else can suggest. But they are not the best, if the diagnosis of the refraction has been the only object, or even if it has always been the main object. For when these cases are properly studied from the standpoint of muscle imbalance, the view obtained of them is more comprehensive. It is desirable, therefore, to consider for a moment one or two underlying principles which assist in establishing a proper diagnosis.

(*A*) First, we should separate, as distinctly as possible, the different elements which combine to form the clinical features of any case. To do this we naturally measure the condition of the refraction thoroughly, learning the range of the accommodation and the resistance which it has to overcome. Also, by the measurements indicated on the record blank we learn the static and dynamic condition of the different groups of extraocular muscles. Suppose, for example, we have what might be called ordinarily a case of hypermetropia with exophoria. When such a case is tested exactly and described in terms of imbalance, we would find a case of compound imbalance, the different elements being: (1) a relative insufficient accommodation; (2) an exophoria perhaps of the passive variety; and (3) insufficient torsion. If the practitioner wishes to be very exact, he would make a diagram of this, showing just the amount of imbalance produced by each of these elements, then he would note the amount of vertical imbalance or anæmia, or whatever else might be present as other elements in the case. Nearly every one endeavors to obtain a definite idea like this of each case, although the process is not always clear, nor is it clear to what extent the object has been attained.

(*B*) We should determine as nearly as possible the relative importance of each element in the compound imbalance.

But it may be asked how we are to know which group of muscles is principally at fault. Unfortunately there is no infallible sign to determine that, but in any case of compound imbalance there are one or two points which give quite reliable indications. They are:

(*a*) The amount of one form of the imbalance as compared with the other forms. Thus when the amount of excessive convergence is much greater in proportion than the excessive accommodation or excessive torsion, we naturally turn our attention to the convergence.

(*b*) The imbalance of the intraocular muscles is usually more important than that of the extraocular muscles.

(*c*) A decided imperfection of torsion is usually of more importance than an imperfection of convergence.

(*d*) The character of the headache is apparently worthy of note. In this condition we shall see that headache, especially of a frontal character, is dependent upon efforts at accommodation. When this symptom is prominent, other things being equal, it points toward imbalance of the intraocular muscles as an important factor.

The treatment of compound imbalance will be considered in the last division of this chapter.

CHAPTER IV.

DIVISION II.

EFFECTS OF THE OCULAR MUSCLES ON THE EYE ITSELF, ON NEIGHBORING STRUCTURES, AND INDIRECTLY ON DISTANT PARTS OF THE BODY.

These effects sometimes accompany simple imbalance, but as they are much more frequent with compound imbalance, it is better to consider them in this connection. It is difficult to say whether they should be called symptoms or sequelæ, but that is rather a question of arrangement. In a subsequent chapter we shall consider the symptoms which may be referred to the eye or its vicinity from morbid conditions in other parts of the body.

SUBDIVISION I.

Effects of the Intraocular Muscles on Intraocular Structures.

§ 1. **Ciliary Muscles.**—What effect does use of the ciliary muscle in an unusual degree have on its own form or structure? This is an old problem, and one to which a great deal of study has been devoted. Nearly half a century ago, Merkle (B 79) showed how the form of the ciliary muscle changes with various conditions of the refraction. This clue was followed out by Ivanoff and Arnold (B 81). The former showed, apparently beyond doubt, that it was really muscle action which produced the modifications in the form of the ciliary body, and that these were not secondary to alterations in the form of the globe. This view has been confirmed by several other students of the subject (B 85–86). There are several aspects of this question which are by no means clear, but clinical facts accord in general with the results of anatomical investigations.

For example, it is a common observation that effort of the accommodation can produce hyperæmia of the ciliary vessels even in a normal eye. It certainly can do that in an eye in which there is already a cyclitis, and cases like that of Roosa (B 1081) are by no means rare, in which a typical cyclitis follows a prolonged effort of accommodation. We must conclude therefore that imbalance not only may, but does occasionally, produce a cyclitis.

§ 2. **The Iris.**—We know that in the act of accommodation the circular fibers of the iris contract, and the whole membrane becomes thinner and more tense, so that after these efforts have been continued for years, especially as middle life approaches, the pupils have become permanently smaller, and the radiating fibers more stretched and less elastic. Indeed, this condition can be produced artificially by eserin, and we find it sometimes prematurely in persons whose occupations demand excessive and prolonged efforts at near work.

As the iris is practically a part of the ciliary body, what has been said of inflammation of the latter applies to the former also. Indeed, we have long known that inflammation of the iris is aggravated by efforts of accommodation, and our first effort is to place its fibers at rest with a cycloplegic, with colored glasses, and in every other way possible (B 1073a).

§ 3. **The Choroid.**—When studying the anatomy of the ciliary body we saw how its fibers stretch backward into the choroid proper. It is therefore not surprising to find that excessive or long-continued efforts of accommodation often affect also the posterior portion of the uvea. This supposition is supported by clinical evidence which, although not abundant, is of such a character that it cannot be ignored (B 1076). Care must be exercised not to refer such pathological changes as we see in the choroid to excessive effort of accommodation, when they may be due to entirely different causes. Thus a number of writers on this subject, when mentioning eye-strain as a cause of choroiditis, speak of the cases which occur with myopia. Now it is evident that the myope does not use his accommodation as much as the emmetrope, certainly much less than the hypermetrope.

Evidently it is illogical to ascribe such changes as occur in the choroid of a myope to eye-strain, when the facts indicate that these are really due to distention of the globe and to the traction on the choroid which comes from that distention, and not from the effort of accommodation (B1084).

In addition to the changes which take place slowly in the choroid as the effect of long-continued contraction of the ciliary muscle, there is good clinical evidence to show that in occasional instances, at least, a well marked, acute inflammation may follow an unusual effort of accommodation. No comment is necessary to show the necessity of the exact correction of ametropia and of the imbalance which accompanies it.

§ 4. **The Retina.**—If we recall how intimately the retina is connected with the choroid at the ora serrata, it is fair to infer that traction upon the choroid also means at least some traction on the retina, but we do not know to what extent that occurs. This is another field in which careful observation and judicial opinion as to the facts observed will probably yield fruitful results. The difficulty heretofore has been the same that we find so frequently in different aspects of the study of the ocular muscles—the lack of an accurate definition. Thus there is need of a precise meaning for the term "hyperæmia of the retina." We have not agreed as to the clinical pictures which we are to associate with a normal retina, as to what constitutes hyperæmia or where hyperæmia passes into a real inflammation. Therefore, until some one has furnished the data with which to form a reliable definition of "hyperæmia of the retina," all statements to the effect that this accompanies unusual efforts of the ciliary muscles are to be received with caution.

§ 5. **Changes in the Macula.**—There are a considerable number of clinicians who think they have seen changes in the macula which are the result of excessive accommodation. Unfortunately most of those who assert that such "changes" do occur, are by no means definite in stating just what they are. When we examine the statements carefully, it seems that a few observers have noticed in a very small percentage of cases that the vessels in the vicinity of the macula

are unusually abundant, or that the macula has the "punched out" appearance occasionally described. Yet no reliable writer pretends that such changes occur except in an exceedingly small percentage of cases.

§ 6. **The Optic Nerve** is also possibly affected by excessive accommodation. Probably no one has studied this question more carefully than Schoen (B 1077, p. 186). He made an ophthalmoscopic examination of 6689 eyes especially with reference to the frequency of excavation of the optic nerve as that occurred at different ages. He found that in children under ten only about eight per cent. showed any excavation, but that proportion generally increased until it reached about sixty-five per cent. in persons over sixty years of age, or forty-three per cent. of all the eyes showed excavation more or less pronounced. This gradual increase in the ratio of eyes exhibiting such excavation had been observed also by others.

A more careful examination of these eyes showed also that the percentage of excavation was greater in those whose refraction was such as to demand unusual effort of the ciliary muscle. In this series there were 1532 hypermetropic eyes, and these showed an average of sixty-eight per cent. with excavation of the optic nerve. Among them also the percentage of eyes in which the excavation was very decided was particularly large. There were also 1086 eyes with marked astigmatism and among them an average of sixty-five per cent. showed more or less excavation. Of these also the more marked types of the excavation were particularly abundant. In a word, these figures indicate that there is a direct relation between the amount of effort exerted and excavation of the optic nerve.

It is not easy to understand how the effort of accommodation can affect the fibers of the nerve. The explanation which has been offered by Schoen we may accept as the most plausible thus far proposed. In Fig. 30, A represents the normal eye. The arrows indicate the direction of the traction of those fibers of the choroid which are extensions of the ciliary muscle. As these fibers posteriorly are indirectly connected with the optic nerve, it is easy to appreciate that if traction is made toward *c*, the direction of the fibers of

the nerve may be changed from that seen in A, to what we see in B.

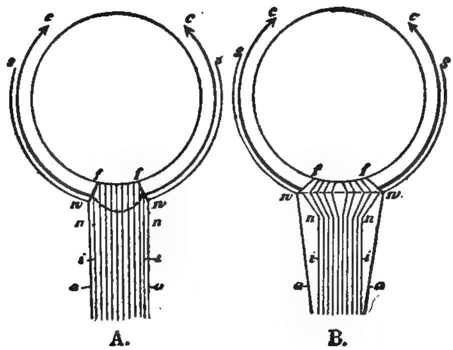

FIG 30.—How ciliary action may produce an excavation of the optic nerve. (Schoen.)

§ 7. **Eye-Strain as a Cause of Glaucoma.**—We find it often contended that eye-strain is a cause of glaucoma (B 1073). This idea has been strongly championed by Schoen. Indeed, he makes the treatment of the refraction the first consideration (B 1082). But the facts indicate that contraction of the ciliary muscle does *not* produce increase of intraocular tension.

(*A*) There is no *a priori* reason why this should occur. No matter how much the ciliary muscle or the lens or both may change their form in this act, there is nothing to indicate that in doing so these structures occupy more space than when the eye is at rest.

(*B*) Manometric experiments upon animals give no indication of such an increase of tension (B 1075). Studies of this kind have been made by several observers and the opinion seems to be almost unanimous. Perhaps the most conclusive evidence was furnished in the work done by Hess and Heine (B 1079, 1079 a), which indicates that no such increase of the intraocular tension takes place.

(*C*) But it is usually argued that the very earliest symptom of simple glaucoma is an increasing presbyopia. That has long been recognized by ophthalmologists, although un-

fortunately it is not appreciated by opticians. As to this point, however, we should remember that:

(*D*) The relief of the effort of accommodation by means of convex glasses is not sufficient to cure or even arrest the glaucoma. This is abundantly shown by cases which occur occasionally in the hands of physicians, and very frequently in the hands of opticians. It may be objected that such cases progress from bad to worse simply because the glasses prescribed are not suitable, but that is simply begging the question. Unfortunately, too, the fact is that cases of glaucoma do go on to blindness in the hands of the very men who insist that such cases are curable by glasses alone. Of that there is actual record.

(*E*) The local medical treatment of incipient glaucoma is the use of eserin. It is a treatment which, although far from reliable, is almost universally used. This drug does not relax the accommodation, but, on the other hand, causes it to be exerted to a still greater extent.

(*F*) The use of atropin or any other cycloplegic is not advised, even by the most strenuous advocates of the theory that excessive accommodation is a cause of glaucoma. On the contrary, it is a well known fact that glaucoma, even in the acute form, may be the direct result of the use of atropin.

In view of the facts thus far presented, we must conclude that excessive accommodation is not a cause of glaucoma, and, moreover, that persistent attempts to relieve it by glasses alone, ignoring, on theoretical grounds, the advantages of eserin or the still greater advantages of operation, are unjustifiable, if not criminal.

§ 8. **Are Peripheral Opacities in the Lens a Result of Eye-Strain ?**—In spite of our great ignorance of the different causes of cataract, it is quite certain that the central opacities can all be excluded from the present consideration. But Schoen has shown an apparent relation between peripheral opacities in the lens and the action of the ciliary muscle which should be noted (B 1089).

First, we should recall the manner in which the lens is attached to the ciliary process by many bands, such as have been already described (Vol. I, Figs. 38, 39, and 40).

Second, let us see what happens in the development of peripheral opacities. On section of the lens with such opacities, we find that the opaque fibers are near the capsule and ordinarily lines of opaque cells are parallel to the capsule. But the interesting fact is that at the point where one of the fibers from the ciliary process is attached to the capsule of the lens, the line of opaque fibers sometimes bends distinctly outward toward this point of attachment. Schoen gives several photographs of sections of the lens in which this arrangement can be seen, as in Fig. 31.

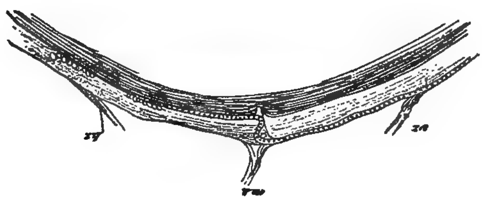

FIG. 31.—Section of the lens capsule at its edge. Three fibers of the zonula are also shown, and near the attachment of one of these (rw), opaque cells bend down to the periphery of the lens.—(Schoen.)

From this it seems very probable that the traction made by the fibers from the ciliary process does have some effect upon the form of the opacity in the lens.

Third, peripheral opacities in the lens are extremely frequent. Among the 6689 cases examined by Schoen he found peripheral opacities in 1140. This number may seem almost incredible, but in spite of the rather unusual conclusions sometimes drawn by this author, his data seem to have been collected carefully and conscientiously.

In view of the foregoing we may conclude that the relation between the fibers of the ligament of Zinn and the development of peripheral opacities. is such as to indicate that traction upon the ligament has in some way a direct connection with the form and position of these opacities.

CHAPTER IV.

DIVISION II.

SUBDIVISION II.

Effects of the Extraocular Muscles on the Globe.

§ 1. **Effects on the Cornea.**—When considering the possible effects of the extraocular muscles upon the globe, we should understand, if possible, whether we have to do with normal muscles acting upon a normal globe, or abnormal muscles upon a normal globe, or abnormal muscles upon an abnormal globe. It is by no means easy in any given case to decide which of these conditions exists. Thus far we lack sufficiently exact standards of measurement to determine the condition of the muscles themselves, but no one can study this aspect of the question without being convinced that the extraocular muscles do affect the form of the globe.

One of the most significant facts in this connection is the manner in which astigmatism develops, or changes its axis, as the result of changed action of the recti (B 1091, 1092, 1093, 1098). Not infrequently the cornea of some young person is measured and found to be practically free from abnormal curvature, but subsequent examinations from time to time show that an irregularity of curvature not only develops but increases in degree, and that sometimes also the direction of the axis changes (B 1103, 1104, 1107). It is generally agreed that what we call acquired astigmatism with the rule is due, in a considerable percentage of cases at least, to the pressure made upon the globe by the upper or lower lids. Indeed, with the ophthalmometer we can often distinctly see the cornea change its curvature (B 1100). In other cases we have the development of astigmatism with an oblique axis or against the rule (B 1095). There is no way of explaining that, except by pressure of one or more of the groups of the extrinsic muscles. In this connection attention should be called again to the cases in which exophoria is associated with astigmatism at an

oblique axis, or against the rule. The question why these two are often associated would probably well repay careful investigation. If we could learn just what that relation is, it would not only help us to correct more intelligently the astigmatism, or the exophoria, or both, but also serve as a clue to the solution of similar problems involving the action of other groups of extraocular muscles.

The effect of the lid muscles primarily and of the extraocular muscles secondarily on the shape of the cornea is also seen in certain occupations (B 1103). Javal and Bull (B 1090) were among the first to call attention to the fact that pressure on the globe is one of the causes of astigmatism in painters and others whose occupation requires them often to pinch the lids together.

It is certain that artists constantly find it desirable to produce artificially an astigmatism in their own eyes in order to obtain the best effects in the blending of color. For, in certain styles of painting, imperfect vision is rather an advantage. It is well known that when pigments are mixed on the palette they do not produce colors as pure as when those colors are blended either by throwing one upon the other as we can with the spectrum, or by placing them in close juxtaposition, and blurring the retinal image which they produce. Now when the artist wishes to obtain a clearer appreciation of the results of the blending of two pigments which he has placed side by side on the canvas, he can sometimes produce artificially, for an instant, an astigmatism in his own eyes, such as we see with the ophthalmometer, by pinching the lids forcibly. Probably also he heightens the effect when he tips the head from side to side as he examines his work critically. These facts about the blending of colors and the relation of art to eyesight I have elaborated elsewhere (B 1099).

§ 2. **Effects on Intraocular Tension.**—Long ago it was suggested by Arlt that the broad tendons of the recti, and especially of the two obliques (Vol. 1, Fig. 16), might press on the globe sometimes in such a way as to impede the return of the venous blood through the venæ vorticosæ, and thus increase the intraocular tension. To decide this, Fuchs (B 15) examined a number of these globes, but found that

the points of exit of most of these veins were not in a position to be greatly affected by the extraocular muscles. While the evidence thus presented by Fuchs tends to show that this factor is not a very potent one, still in view of the importance of the question it would be interesting to have it studied again by more modern methods of injection and staining.

Although we are still in doubt concerning that anatomical question, it is certain that the extraocular muscles do exert a very immediate and important action upon intraocular tension. This has been shown by manometric experiments, especially such as have been made by Hess (B. 1079). It has been clearly proved by experiments upon different kinds of animals that as long as the recti exert their normal pressure the mercury in the tube of the manometer rises rapidly with each motion of the globe. On the other hand, when the recti muscles are divided, passive motion of the globe shows no such variation of the intraocular pressure. These facts have been too often overlooked in the etiology and even in the treatment of glaucoma.

CHAPTER IV.

DIVISION II.

SUBDIVISION III.

Effects of the Ocular Muscles on Neighboring Structures.

In the effects which have thus far been mentioned as produced by the intra- and extraocular muscles, the relation between cause and effect is more or less direct.

We now come to another group of conditions which seem to be, usually, at least, the result of some action of the ocular muscles. In this group, however, we do not know from the facts now in our possession how it is possible for any or all of the ocular muscles to produce such effects, except that the headaches which are now to be referred to depend on what we call associated muscle action. We shall see in the next subdivision that abnormal action of the ocular muscles does affect parts of the body which are quite remote from the eye,

but at present our attention is directed to the effects produced upon structures in the immediate vicinity of the globe.

§ 1. **Hyperæmia of the Conjunctiva.**—This was included among the cardinal symptoms of imbalance. Its occurrence has generally been explained by supposing that the nerve impulse which was necessary to the ocular muscles also brought an excessive amount of blood to the conjunctiva. There is a basis for such a supposition in the fact that the conjunctiva receives its blood largely from branches of the same vessels which supply the muscles. It is desirable, however, to avoid discussing that or other theories, but it should be noted that when the hyperæmia exists in a sufficient degree, there is associated with it frequently a feeling of discomfort, of itching, or even of distinct pain, which causes the person to close the lids and rub the eyes. The continued use of the eyes under such circumstances is apt to cause the hyperæmia to pass over into a well defined though simple form of inflammation of the conjunctiva.

§ 2. **Increased Lacrimation.**—What has been said here of hyperæmia of the conjunctiva applies also to increased lacrimation. This was also included among the few cardinal symptoms of imbalance. Although it is not as constant a symptom as any of the others in that group, we know that it does occur frequently when the effort of accommodation has been long continued or excessive. We are, however, ignorant here also as to exactly how this effect is produced.

§ 3. **Corneal Inflammation.**—French writers have called attention to cases which apparently show that abnormal action of the ocular muscles, especially in astigmatism, produces inflammation of the cornea (B 1109-1110). This is in accord with the practice of many American ophthalmologists, who are accustomed to advise the use of glasses even in early life, when there is any tendency to corneal inflammation, but the evidence which we have thus far by no means proves that inflammation of the cornea is produced by imbalance.

§ 4. **Blepharitis.**—When Roosa first called attention to a relation which seemed to exist between astigmatism and blepharitis (B 1111) his statement was received with considerable incredulity. The experience of more than a quarter

of a century, however, has apparently justified his conclusion, and now medical opinion seems to have crystallized concerning two facts.

First: Not infrequently we find blepharitis associated with astigmatism, and

Second: After correction of the astigmatism, the blepharitis either disappears or shows itself more amenable to treatment than before. These two difficulties existing in the same individual might be a coincidence, but the beneficial effect of correcting an ametropia indicates a direct relation between them.

It must be acknowledged that we are totally unable to explain why any such relation should exist. The attempt to do so would lead here too far afield, and we can only call attention to the apparent connection between the ocular muscles and the blepharitis, leaving the details of the question to some future student.

§ 5. **Headache Resulting Directly from Imbalance.**—Among the cardinal symptoms of imbalance a conspicuous place was given to headache. All practitioners agree that this is not only the most constant, but very frequently the most important symptom with which the ophthalmologist has to deal. Books have been written on the subject, and there are articles innumerable which call attention to the relation between "headache and eye-strain." This relation between the eyes and headache is not a discovery of recent years, but was known by some of the earlier writers. And yet, in spite of all that has been written or said concerning it, our ignorance of the subject is almost as great as it was fully half a century ago. If we are to advance, therefore, in our knowledge of this important symptom, it seems worth while to consider at the very outset the causes of our ignorance. Head (B 1114) has pointed out one reason for this clearly when he says that what we need is not the superficial study of a very large number of cases of headache, but the careful study of a few. It is also evident that a large part of our ignorance depends on imperfect nomenclature, or rather the indefinite use of terms. The word headache in itself may mean much or little and almost anything. Head has also

shown that when speaking of headache we should not only specify its locality—that is, the part or parts of the head over which the pain is experienced,—but also whether that pain is accompanied by tenderness, and as nearly as possible ascertain the area of that tenderness. This can be done roughly, by pricking the skin with a pin.

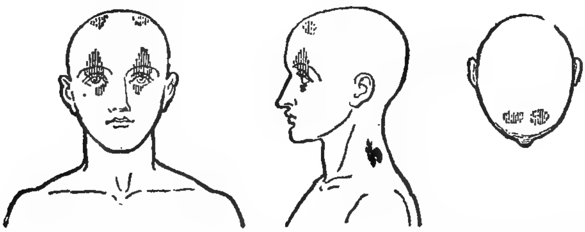

FIG. 32.— Areas of superficial tenderness in a case of hypermetropia (Head).

As there has been a decided looseness in using the term headache, so there has been a similar laxity in using the term eye-strain when related to that headache. Such a term teaches us but little. What we wish to know is exactly the kind and degree of the ametropia, or, still better, the kind and degree of the imbalance, simple or compound, which is associated with headache of this or that variety. Accurate investigation on points such as these would tend greatly to clear up the cloud of ignorance which now envelops what we call headache, and what is usually called eye-strain. Until these studies are made, our ignorance of the subject must remain as dense as at present.

Having thus glanced at the causes of our ignorance concerning headaches, it may be said that from data now at our disposal we are warranted in dividing so-called ocular headaches into three great groups.

(1) Those which are *directly* the result of a contraction of the accessory muscles of accommodation.

(2) Those which are *indirectly* the result of imbalance; and

(3) Those which are a reflex from disorders of the stomach or from other parts of the body.

At this point we shall consider only the first group.

Apparently in a large number of headaches this symptom is due to a tension of the accessory muscles of accommodation. The reasons for this conclusion are:

(*a*) In extreme effort at accommodation we can often see, from the wrinkles at the root of the nose and on the forehead, that the accessory muscles are in this state of contraction.

(*b*) We find that in addition to the vertical folds in the skin caused by the corrugator, there are also horizontal lines on the forehead, formed by the contraction of the anterior portion of the occipito-frontalis, and by the muscular fibers on the face which are more or less directly attached to it. The pathological action of the accessory muscles thus influences the facial expression. See Fig. 33.

FIG. 33.—Wrinkles on the forehead produced by the contraction of the accessory muscles of accommodation.

(*c*) We know that when the anterior portion of the occipito-frontalis is contracted the posterior portion contracts also. It is an ordinary observation that an occipital headache, with pain extending even to the upper part of the back, is relieved when suitable glasses are worn, and returns when those glasses are removed.

(*d*) We know that pressure across the forehead by a cloth tightly stretched or by a broad rubber band or other device will sometimes modify the character of these headaches, even when the degree of accommodation remains the same.

(*e*) Finally, in certain cases at least, complete division of the vertical fibers of the occipito-frontalis will lessen or entirely relieve, at least temporarily, severe headaches which

before were associated with efforts of accommodation. More extended reference will be made to this point toward the end of the chapter on operations.

The importance of these accessory muscles in their relation to headaches is so great that much space was given to their consideration in the first volume. It is true that headaches which result from contraction of the accessory muscles of accommodation may also consist in part of sensations which are referred to the head from a lesion which exists in some other part of the body. The inevitable conclusion seems to be, however, that the contraction of these accessory muscles is in a very large percentage of cases an important element in the production of what we call a headache. The practical bearing of this is too evident to require any elaboration. It takes this very annoying symptom out of the realm of mystery, and places it in close relation to the act of accommodation.

§ 6. **Torticollis.**—The theory that torticollis or even scoliosis is in some instances the result of effort made by the eyes is not new. More than thirty years ago attention was called to this subject, and since that time we find every now and then curious examples of an asserted connection between torticollis and apparent or latent deviations of the eye. The number of cases is now so considerable that there can be no question as to the fact that torticollis occurs with certain forms of imperfect action of the ocular muscles. It is proper to call attention briefly to these rare cases in this connection, because the tipping of the head is indirectly due to the action of the ocular muscles.

But in the large majority of these cases of torticollis which are ascribed to the eyes, we find a paralysis of some kind. In the chapter on the paralyses we shall see that one of the ordinary symptoms is the turning of the head of the patient toward the affected muscle. It is easy to understand therefore that if such an enforced position of the head were maintained for a long time there would result the condition which we recognize as torticollis or scoliosis. This and allied symptoms will be considered in another part of these studies.

CHAPTER IV.

DIVISION II.

SUBDIVISION IV.

Effects of the Ocular Muscles on Other Parts of the Body.

(Indirect Effects of Imbalance.)

Preliminary Considerations.—We now approach another group of effects which the ocular muscles produce, or are supposed to produce. These are principally on parts of the body remote from the eyes. The effects are not as direct as those thus far studied, and are probably produced through the action of the sympathetic nervous system. They are as yet only imperfectly understood. While it is an established fact that the ocular muscles can produce some such effects (B 1122 to 1127), their number and importance have been unduly exaggerated. Before attempting even an enumeration of these "reflexes of eyestrain", as they are usually called, let us glance at the evolution of our knowledge of them, and ask how we can explain or recognize their existence.

(*A*) Historical Retrospect: When Donders wrote, more than half a century ago, and for some time after him, no one suspected that the action of the muscles could produce much inconvenience beyond the cardinal symptoms of imbalance, or what was then called "asthenopia." Some practitioners still retain these views of the subject either because they have not watched the enlarging meaning of "asthenopia," or because they have grown suspicious of a certain class of medical literature which is apparently the rank growth of our western soil.

One of the first to call attention to the relation between ametropia, or what we may here call imbalance, and abnormal conditions in other parts of the body was S. Wier Mitchell (B 1122). While the subject has been studied more generally in this country than elsewhere, it must be admitted that a vast deal of nonsense has been written here concerning it.

But the gist of the matter is that gradually increasing clinical experience has made it necessary to modify our idea of asthenopia in two important details.

(*a*) Its scope was enlarged as to symptomatology. By "asthenopic symptoms" we learned to understand not simply the blurring or discomfort with near work, frontal headache, hyperæmia of the conjunctiva, or slight lacrymation, but headache in the vertex or in the occiput. It included pain extending upon the neck and shoulders, or nausea, especially with persistence at near work, or it grew to include many reflexes of a neurotic type, which in that individual were dependent upon the use of the eyes.

(*b*) Its scope was enlarged also as to the etiology. We learned that many of these symptoms may result directly from an imperfect action of the ocular muscles, and also that certain disturbances of the general system, acting as a primary cause, may occasionally affect the ocular muscles and thus produce symptoms which when taken together are called "asthenopia."

It is interesting to observe that the widening of the meaning of this term "asthenopia" as to locality has been a gradual one. That is to say, the earlier writers for the most part noticed only that parts of the body in the immediate vicinity of the eyes were affected by the imbalance. Those of a slightly later date included symptoms in parts of the body a little more remote from the eyes, while the most recent writers include symptoms which appear in distant parts of the body.

(*B*) Sympathetic nerve fibers from the eye to the neck. No description of these fibers was attempted in the first volume, as that one dealt more particularly with the muscles themselves and their nerve supply. Nor is it possible here to give more than a glance at the connection between the eye and the neck through the fibers of the sympathetic. It is worth while, however, to recall the anastomoses between the ophthalmic ganglion and the carotid plexus, as this is seen, for example, in Fig. 34. Another probable connection between the ciliary ganglion and the cervical sympathetic is through one or more fibers which pass from the lower portion

of that ganglion to the spheno-palatine ganglion, thence to the carotid plexus lower down, and along any one of the fibers of that plexus to the ganglia of the neck (B 1133–1138).

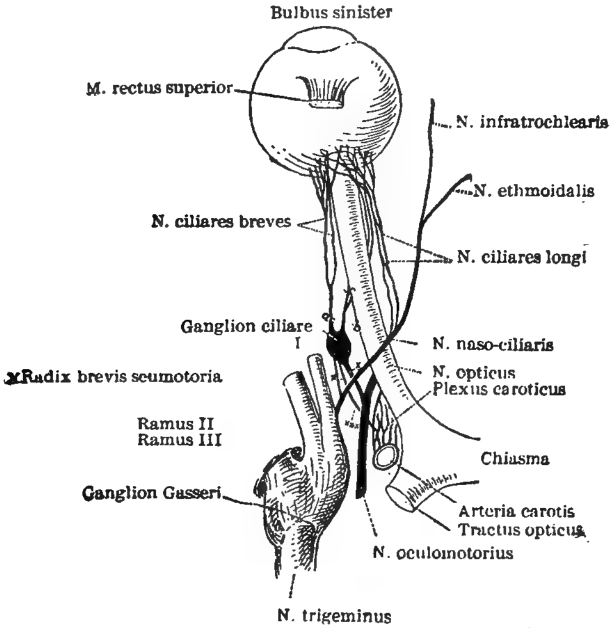

FIG. 34.—Connection between the ophthalmic ganglion and the carotid plexus (Pltz).

Over such minute filaments of the sympathetic, and probably over others equally minute and still undiscovered, nerve impressions find their way from the globe to the cervical ganglia or thence to distant portions of the body, and there make their presence manifest by what we call in our ignorance a *reflex*. That may be a sensation of discomfort or a real pain referred to that locality. It may also manifest itself by an abnormal function of the part affected, as in variations of the acidity of the gastric juice, or by aggravating an abnormal condition already existing, as in neurasthenia.

On the other hand, a similar nerve impression may travel apparently over the same route but in the opposite direction.

That is, abnormal conditions near the eyes or even remote from them may produce in the eyes discomfort, pain, imperfect function, or aggravation of an abnormal condition already existing. As pain is the most noticeable of these reflexes, it should be remembered that analogous referred sensations also occur in other parts of the body as, for example, the pain referred to the knee in hip-joint disease (B 1140–1141). When a reflex to the eye manifests itself in the form of a muscular spasm or paresis, we have of course a distinct imbalance resulting.

(*C*) Criteria by which to determine whether a given symptom is the result of muscle imbalance. Before we can safely assert that a relation of cause and effect exists between the eyes and any special symptoms complained of, we should be able to establish:

(*a*) A relation in time. The reflex symptoms should follow the disturbance of the imbalance or be coincident with it, whether that is produced artificially or by disease.

(*b*) There should be a relation in degree. Ordinarily the amount of imbalance is in some proportion to the severity of the reflexes. It is true that there are many exceptions to this. For some unknown reason the severity of the reflexes is occasionally entirely out of proportion to the amount of imbalance. Yet when they are in proportion to each other they naturally tend to confirm the existence of a relation between the two.

(*c*) The partial or total correction of the imbalance should produce a corresponding effect upon the suspected reflexes. While there are many exceptions to this rule also, it holds true as one of our guiding principles.

(*d*) Everything which may be considered a secondary or a contributing cause in producing the reflexes should be eliminated. Although this is last on the list, it is clearly of prime importance. When we recall our ignorance of certain parts of the nervous system, it is evidently impossible to be sure that some nerve centers quite remote from those relating to the eyes are not also at fault in the production of the symptoms before us. Indeed, unless there is a real connection in time, in degree, and in variation under treatment between the

cause assigned and the suspected reflex, we can never be sure that the latter is really a result of the former.

(*D*) Frequency of such reflexes, especially in America. More than a quarter of a century ago Beard (B 1120) called attention to the so-called nervous tendency of certain classes in America. He says: "There is a large family of functional nervous diseases which are increasingly frequent among the indoor classes of the civilized countries, and they are especially frequent in the northerly and easterly parts of the United States." In an analysis of 1079 cases of asthenopia by Noyes, he showed that these cases were much more frequent in the United States than elsewhere. Roosa and Bull are of the same opinion (B 1121), and dispensary records in this country usually show a larger percentage of these cases than elsewhere.

It is true that such statistics may be misleading, because, when the average American, rich or poor, discovers that his vision is not quite perfect, he takes steps at once to obtain suitable glasses. Moreover, it is the habit of the general practitioner in this country to advise patients who suffer from headaches to have their eyes examined, if simple internal remedies do not give prompt relief. It is also certain that the average American ophthalmologist has better appliances for testing such cases, and has given in general more care to details in refraction than has his European colleague. For these reasons, cases of imbalance may seem relatively more frequent than is really the case.

But there are several reasons why they are actually more common in this country. These are:

(*a*) The careless manner in which Americans use their eyes under unfavorable circumstances. The abundance of our newspapers and magazines, often badly printed, the habit which we have of reading on the cars, and often by imperfect illumination, is sufficient to account for a certain number of cases.

(*b*) The hurry and mental strain of our American life make unusual demands upon the nervous system; or

(*c*) Reflexes are shown in the eyes which are due to difficulties of digestion. As certain diseases of the alimentary

tract are specially frequent in this country it is probable that they produce reflexes in the eyes. This is undoubtedly an important point. It is certain that more meat is consumed by the average individual in America than in any other country, except perhaps in England. But neither the meat nor any other food is masticated, in general, as thoroughly as it should be. Our chronic condition of hurry does not permit that. The imperfect digestion which results, reacts on the nervous system and indirectly on the ocular muscles. This is not a theory, but the process can be demonstrated—at least in certain individuals.

(*d*) The excessive heat of our homes in winter, with the corresponding relative dryness of the atmosphere, undoubtedly causes low grades of conjunctivitis, and this in time sometimes gives rise to symptoms of imbalance.

Other causes also contribute to the same result.

(*E*) The conclusions here given are not final. It should be remembered that the conclusions stated are based on data obtained by methods of measurement which are quite imperfect, as compared with those which were found in the earlier part of this study to be necessary or desirable. Thus although we may know the ametropia and sometimes an outline of the imbalance which existed in many of the cases thus far reported, the observers have usually failed to measure, or at least failed to report, the actual condition of the ciliary muscle, of the relative accommodation, of the relative convergence, of almost everything concerning the torsion, and many other important details.

In a word, the conclusions here given are simply such as must be drawn from the comparatively few data now at command. In spite of the abundance of literature, good and bad, relating to what is usually called eye-strain, the opportunities for real investigation in this direction are many, and it cannot be long before some student will write this chapter much more completely than is now possible.

CHAPTER IV.

DIVISION II.

SUBDIVISION V.

Effects of the Ocular Muscles on the Nervous System.

§ 1. **Headaches Indirectly the Result of Imbalance.**— We have already studied the headaches which are *directly* the result of imbalance. We now come to a second group which are *indirectly* the result of it. This second class may be defined as the headaches which result from a muscle imbalance, and are preceded by or accompany disturbances in other parts of the body. The absence of all tenderness or similar local symptoms excludes them from the first group, and the absence of any discoverable lesions or sufficient cause in the body, apart from the eyes, excludes them from a third group of headaches which will be discussed later.

At first glance, this second group would seem to be simply a limbo for undetermined cases. That is not quite true. For it is possible to produce such a headache artificially. If glasses which are improperly made are worn by certain patients, they are soon conscious of slight nausea, and almost immediately after complain of a distinct headache. This is confined principally to the eyes and forehead, but has none of the other features mentioned in the headaches which result directly from imbalance, except that when that pair of glasses is changed for another, the discomfort rapidly subsides. Otherwise these patients may be apparently types of perfect health. Such cases are familiar to us all.

In a certain sense these might properly be placed in the first group of headaches, as the ache is perhaps due, in part, directly to the action of the accessory muscles of accommodation. But there is also good reason to think that the nervous disturbance is first transmitted over the fibers of the sympathetic to the stomach to produce the nausea, and then either reflected back to the eyes, or at least the ache follows the nausea. Apparently, therefore, we are warranted in placing these cases of headache in a special group and considering them the indirect effect of muscle imbalance.

It is evident that most cases of sick headache (migraine) belong to this group. At any rate it is convenient to place them here in such a classification. The number of articles or even books written about sick headache is also large, but the actual facts concerning its causes, ocular or otherwise, its pathology, and therefore its treatment, are few. Consequently, it is only necessary to cite in the bibliography a few references with the hope that the subject will be properly elaborated by some future student (B 1143-1153).

§ 2. **Fatigue.**—Normal eye muscles, when used to excess, or those which are imperfectly balanced frequently give rise to fatigue which is local or general. The local fatigue has been already mentioned. The fatigue referred to here is that which, beginning in the eyes, extends to other parts of the body. Every one has noticed that if, while reading, he almost drops asleep, the print becomes blurred, diplopia is often distinctly present, the fatigue extends to other muscles, or it becomes so general that in spite of all incentives to the contrary the book or near work is involuntarily laid aside, and the attempt for the time abandoned.

The point is that in some persons the residual energy is small all the time—as small as in a healthy person after a day of hard work. In such persons it is comparatively easy for the ocular muscles to produce a feeling of general fatigue.

§ 3. **Neurasthenia.**—When the fatigue does not disappear with rest, when it becomes a condition constantly apparent, and when it is associated with various other disturbances, it is usually called neurasthenia. There is no longer any doubt of the fact that, in certain individuals, imbalance of the ocular muscles with the resulting eye-strain is one of the causes of that indefinite group of symptoms which we class together under that one name. Some writers would have us believe that eye-strain is usually a prominent cause, occasionally the only cause. But that is an extreme view. When we sift the evidence carefully we may find that the imbalance sometimes does play a more or less important causative rôle, but seldom, if ever, is it the principal one. This phase of the subject might be elaborated almost

indefinitely, but this brief statement concerning it must suffice (B 1158–1163).

§ 4. **Hysteria.**—Although it is difficult to define this condition exactly, we all recognize what is meant by the term. In hysteria it is particularly difficult to arrive at definite conclusions, for the reason that we can not determine what is real and what is imaginary. Almost anything makes these patients better for a short time, and nothing is permanently of avail. More than once I have found it of assistance in the diagnosis to exchange the glasses which the patient brought, for another pair of the same strength, and decided relief was often reported. Again, those who never wore any lenses think their eyes feel better with a pair of plane glasses before them. Such experiences indicate how little confidence can be placed in any statement of the hysterical concerning their condition. The type of this class is the neurotic woman who is overworked, or is still more unfortunate in having too much leisure to think about herself. She imagines there is something the matter with her eyes. At least they do not seem to suit her. Such patients wander about from office to office and when some slight corneal irregularity does exist, they might aptly be called cases of walking astigmatism. One author has said: "Neurotic they are born and neurotic they die." While, therefore, an important part of their care may depend upon the ophthalmologist, their proper treatment often requires also the best judgment and tact of a physician (B 1164–1168).

§ 5. **Spasmodic Muscular Contractions. Chorea.**—This form of nervous disturbance also appears under different forms and in widely varying degrees. Osler (B 1171) refers to some ninety odd varieties. The off-hand statements frequently made, that chorea is always or even usually due to ocular imbalance, are not supported by fact. De Schweinitz (B 1172) examined fifty cases of chorea in children, and says of them: "Hypermetropia and hypermetropic astigmatism are vastly the preponderating condition in the eyes of choreic children, being found in about 77 per cent of the cases; exactly as hypermetropic refraction is the preponderating condition in childhood, being found in 76 per cent. of the eyes of

children in the elementary schools." "The evidence, however, seems quite as lacking that hypermetropic refraction is the basal cause of chorea as it is that the chorea is the cause of the hypermetropia." On the other hand, there are a few cases in which the relation between eye-strain and a chorea is apparently that of cause and effect. Instances of this kind, which are suggestive if not conclusive of such a relation, have occurred to every practitioner of experience. Therefore, *after* anthelmintics and the other simple and reliable remedies have been found unavailing, the eyes should be examined and with unusual care. If we are to condemn any patient, certainly a child, to glasses, the evidence must be as conclusive as possible, especially in these cases.

§ 6. **Epilepsy** is another indefinite term for a group of symptoms of which little is known, but of which much has been written in its relation to the eye. It is desirable at the outset therefore to understand one or two of the difficulties which enter into this part of our study, thus:

(*A*) The term epilepsy means nothing exactly. Some thirty different forms or at least designations of epilepsy have been given (B 1176). More recent writers deal rather with "the epilepsies" (B 1181). Therefore when claims are made for the cure of this condition by means of glasses we do not know what is meant unless in each case the nature and severity of the symptoms are described.

(*B*) A doubtful factor in this problem is the irregularity often found in the frequency of the attacks. It is well known that in a certain proportion of these cases the seizures suddenly cease for a while, apparently without any cause. In forming an opinion, therefore, we must exclude cases in which a really exact record has not been kept as to the number and severity of the attacks for a period of several months before and after any ocular treatment. The familiar general statement that such a case of epilepsy seen in private or dispensary practice has been improved or even cured by glasses, means practically nothing. Therefore, about the only evidence which can be admitted in a strict inquiry is that which relates to patients in institutions or those whose clinical records have been kept with equal exactness.

If we thus agree as to the character of the testimony which is to be admitted in any such consideration, we eliminate at once a large class of cases of rather doubtful character, which have been published even in medical journals of good standing, but apparently rather for commercial than for scientific purposes. With this understanding we are better prepared to glance at the salient points in the testimony as it appears in the literature.

Attention was specially called to this subject by Stevens (B 1174), and naturally it elicited considerable discussion. Nevertheless the facts were questioned, and a commission, consisting of leading ophthalmologists and neurologists in New York agreed to submit for examination a number of cases of chorea and epilepsy in which the diagnosis was well established. The results were found to be in general unsatisfactory, and the rather inglorious ending of the inquiry can be judged best by those who care to turn to the facts as given in the report of that commission (B 1175).

Somewhat later, Todd (B 1177) made an examination of the eyes of one hundred patients at the West End Hospital for Nervous Diseases, London, and compared the average refractive condition with that of fifty healthy persons who had apparently normal eyes. It was found that imperfections of vision were proportionately more frequent among the epileptic, there being, for example, twenty per cent. more who were astigmatic than among the healthy individuals, but as he only took the ametropia into account, the conclusions cannot be considered convincing.

The careful studies made by Gould and Bennett of patients at the Craig Colony for Epileptics at Sonyea, New York, should also be mentioned. An opportunity was afforded to select out of some 600 or more cases those which seemed most favorable for the test. The glasses prescribed were made by a competent optician under the immediate direction of those who conducted the examination, and the details of the treatment were carried out as exactly as possible.

In the next annual report of the Institution the Superintendent gave a table of the cases thus examined and treated, and commented on them by saying (B 1180): "We

regret having to report disappointing results. The table shows that one patient only out of 68 experienced any benefit in his disease while wearing glasses."

In view of these discouraging results, it might be inferred that we are warranted in dismissing the entire subject and concluding that there is no well established relation between imbalance and epilepsy. But considering that epilepsy is often due to some obscure irritation, and also that muscle imbalance certainly does produce some similar reflexes, there are good *a priori* reasons for supposing that imbalance may occasionally produce what we call epileptic attacks.

Moreover, it is certain that some of the cases reported in institutions, and a few not in institutions (B 1178–1184), really do show a distinct relation between muscle imbalance and epilepsy. We are therefore led to conclude:

First, in a small number of cases the attacks are apparently the result of ocular imbalance, and lessen in frequency when suitable glasses are used. This seems true only of the incipient stages, when attacks are slight and rather infrequent.

Second, we need clearer diagnoses of the forms of epilepsy. It is necessary for the ophthalmologist to ascertain with just which one of the epilepsies he is dealing, and to describe that form definitely, if he would make clear its relation to the eye-strain.

Third, we need more careful and exact measurements of the ocular condition and of everything connected with it. Besides learning the probable refraction and something of the static condition of the extraocular muscles, we should learn the position and condition of the lens, the condition of the ciliary muscles, the relative accommodation and relative convergence, and all possible data as to the general condition of the patient. When students are ready to give to these cases the time and care which their complete examination demands, then and not till then can we clear up the relation between muscle imbalance or eye-strain and that complex condition which we call epilepsy.

§ 7. **Other Neurotic Conditions.**—It would require a volume to consider even briefly all of these real or supposed

effects. A few references to them are given in the bibliography (B 1185–1192), but many reports of cases are omitted, because although eye-strain and a neurosis did exist, a relation of cause and effect was by no means established.

Articles which deal also with the general aspects of this subject are abundant, but those also, though sometimes excellent, are necessarily excluded from the bibliography, already very extensive.

The nervous effects may be shown not only in pathological conditions, but in mental or even what we call moral conditions. Thus an examination of the eyes of criminals (B 1194–1195) shows that ametropia and muscle imbalance are much more frequent among this class than is found among other persons. This is not surprising, for imperfect or painful vision during school life tends to make the pupils inattentive and leads to truancy. That in turn is followed by minor offences or occasionally crimes of a really serious character. While this chain of circumstances is far from complete in every case, the facts indicate that the sequence is often followed.

A most interesting set of figures has been collected by Bielschowski and Ludwig (B 1193) concerning the average frequency of ametropia and imbalance among neurotics, but only a mention of these studies is possible here. Strangely enough heterophoria was, on the whole, a little more marked among the normal persons than among the neurotic, but latent vertical deviations were more frequent with them than among the healthy subjects. Any one who may be especially interested in this phase of the subject can study with advantage not only the scientific methods followed in that investigation, but also the care exercised in arriving at the results.

In a word, while it is undoubtedly true that the ocular muscles do exert some effect upon the nervous system, we must exercise constant care not to confuse a simple coincidence with what seems at first glance a relation of cause and effect

CHAPTER IV.

DIVISION II.

SUBDIVISION VI.

Effects of the Ocular Muscles on Parts of the Body Other than the Nervous System.

§ 1. **On the Teeth.**—As one branch of the fifth nerve is distributed partly to the teeth and partly to the eye, it is easy to understand how a sensation might be referred from one peripheral point to the other. Several cases are on record (B 1198) which show that a relation between the teeth and the eyes does exist.

§ 2. **On the Mucous Membrane of the Nose.**—As the nerve supply of the nose is also more or less intimately connected with that of a part of the eye, it is natural that a relation between these two should also have been noticed (B 1199–1203). It is an interesting subject and should be elaborated further by those who have an opportunity of observing pathological conditions both in the eye and the nose.

§ 3. **On the Stomach.**—The question whether muscle imbalance can have any effect upon the stomach is comparatively new and of decided importance.

If we turn first to the various writers on diseases of the stomach we find that only a few make the least reference to any relation of the eyes to that organ (B 1215). But the ophthalmologists of to-day, especially in America, are almost unanimously of the opinion that an imbalance does often produce certain gastric symptoms. That opinion is, as a rule, not based upon systematic investigations or exact study of the question, but on a general impression obtained from daily practice. Thus the following may be quoted from de Schweinitz (B 1208): "We have learned that many so-called gastric troubles, tachycardia, flatulent and other types of dyspepsia, indigestions, night terrors, especially as they occur in children, may have a like origin." In view

of this difference of opinion between the gastrologist on the one hand and the ophthalmologist on the other, it behooves us to discard the opinions of both and examine the evidence on which a verdict may be based. In doing this, we may observe:

First, the abnormal action of the ocular muscles of normal eyes. The simplest illustration of this is when the individual makes frequent efforts to adjust the focus, or to move the eyes in an unusual direction—that is, to exercise the intra- and the extraocular muscles in an unusual and rapid manner. For example, when riding backward in a car, or even when facing the direction travelled, a sensation of nausea is sometimes produced. This is usually increased when the eyes are open, and decreased when they are closed. The same thing occurs with most persons whirling in a swing, or with some when at sea.

Second, the effect of glasses upon eyes which are practically normal. If a dozen pairs of quite strong spherical glasses, or still better cylinders or prisms, be distributed to as many individuals, after a while at least one or more of these persons will wish to remove the spectacles, because of a disagreeable sensation referred to the stomach, usually a distinct nausea.

Third, the effect of glasses upon eyes which are abnormal. This part of the testimony is abundant. It is this, of course, to which the attention of the ophthalmologist is naturally directed. It is part of his daily experience to have patients consult him concerning the cardinal symptoms of imbalance accompanied with a feeling of nausea. That is such a common symptom that the word nausea is printed on many examination blanks. Moreover, the ophthalmologist frequently finds these same patients complaining of numerous other gastric symptoms, hyperacidity, indigestion, eructations, etc. It is also part of the daily experience of the ophthalmologist to see that if suitable glasses are given to these people, in a decided majority of the cases, the gastric symptoms either lessen or disappear entirely. After such experiences, frequently repeated, it is natural for him to conclude that there is a direct relation between the ocular muscles and the stomach.

Fourth. There is another group of facts which points in this direction: some forms of acute inflammation of the eyes are accompanied by nausea or even vomiting. This is seen in acute glaucoma. It indicates a connection between the eyes as a whole and the stomach, but not necessarily the condition of the ocular muscles and the stomach.

Fifth. Finally, the most conclusive evidence of a relation between the ocular muscles and the condition of the stomach is in the effect of glasses upon the total acidity of the contents in a case where that could be conveniently tested. This was in a young person upon whom a gastric fistula had been made. As we knew in this instance exactly what food was given, as it was easy to obtain the stomach contents for the numerous examinations which were made, and as she was in the Buffalo General Hospital where accurate records could be kept, glasses of various kinds and of different strengths were tried, and the results seemed to show beyond question that it was possible to affect the gastric secretion, especially the total acidity, by the use of certain glasses. This, however, was not to any greater degree than we knew long ago, that the gastric juice was also affected by sudden emotions or mental impressions. The findings in this case are corroborated by other similar but less conclusive tests.

We must conclude, therefore, that muscle imbalance frequently does have some effect in producing gastric symptoms, and apparently also on the character of the gastric juice itself.

§ 4. **Other Actual or Supposed Effects on Distant Parts of the Body.**—In addition to the foregoing actual or supposed effects of the ocular muscles upon distant parts of the body, there are other effects which these muscles are thought to exert. Thus it is not improbable that some tachycardia may occasionally result from imbalance. But it is frequently asserted, in off-hand fashion, that reflexes are seen, first on one organ, and then on another, until there are few parts of the body which are not supposed to have been influenced, directly or indirectly, by imbalance of the ocular muscles. Moreover, in a few of the cases reported, the testimony seems to indicate that the muscles may possibly be

one of the etiologic elements, especially in the so-called nervous difficulties of the liver, the kidneys, or even of the uterus. It is doubtful, however, whether the glasses which were thought to improve these conditions did more than relieve some existing eye-strain and thus indirectly comfort the patient. While it is possible, of course, that evidence will be produced which will prove that the ocular muscles do affect still other parts of the body, yet, in the present state of our knowledge such statements are usually unfounded and thoroughly unscientific. In a word, a large part of this portion of the subject is still *sub judice*. All that we can do is to arrange such facts as we have in some order, draw conclusions with caution, and be ready to modify our opinions as further data are presented.

§ 5. **Exaggerated Opinions of the Effects of Eye-Strain.**—If we admit that certain reflexes can be produced by imbalance, the question arises why all reflexes do not come from the same cause? This is dangerous ground. Every step must be taken cautiously, or one is soon lost in vagaries. The reasoning which has led to these extreme views is, in substance, that as comparatively slight degrees of muscle imbalance are accompanied by decided reflexes in certain cases, and as such imbalance is very common, therefore it is the chief or only cause of these reflexes.

The value of this logic can perhaps be appreciated by applying it not to the eye but to a neighboring part of the face,—for example, to the nose. Thus one might also say, as comparatively slight degrees of deviation of the nose to one side or the other are accompanied by decided reflexes in certain cases, and as such lateral deviations are very common, therefore lateral deviation of the nose is the chief or only cause of these reflexes. There is apparently no difference in the reasoning.

It may be urged that some of these cases of nervous reflexes are cured by the adjustment of glasses or by certain operations, and in a few instances this seems to be true, but in most it is not.

Evidently our only way is to agree upon certain criteria, as we have already tried to do, Div. II, Subdiv. IV (*C*), and then to decide accordingly. In justice to those who do not

care to hamper their conclusions by recognized standards, it should be remembered that ordinarily such persons do not intend to deceive themselves or others. They simply can not see facts as the vast majority do. Moreover, there is usually a grain of truth in their various contentions, and the rest of us would probably forget that truth, if the few did not insist on calling attention to it so frequently and so vociferously.

In connection with the exaggerated statements concerning the effects of the ocular muscles upon other parts of the body, it would be an omission not to refer to the efforts which have been made of late years to prove that certain well-known persons—especially authors—have been sufferers from eye-strain. One American writer has a series of so-called "biographic clinics" in which he has shown that most of the persons thus selected for consideration had rather misanthropic views, indigestion, or ill tempers, and therefore concluded that these conditions were due to imperfection of the ocular muscles.

Any ophthalmologist who tries conscientiously to work out a diagnosis and determine whether actual conditions are in any way dependent upon muscle imbalance, or due to other causes, usually finds that question perplexing and difficult enough, even when the patient is living and an opportunity is afforded for frequent examinations under the most favorable circumstances. To such a student it seems a little hasty, to say the least, thus to jump at a diagnosis when the patient is dead and has been dead for many years.

Besides, if this agility of decision is permitted at all, it must be applicable to any case. There is no reason for limiting such conclusions to only a few recent writers who naturally attract public attention. From similar data, we would be forced to conclude that Ezekiel with his lamentations, or Job and other less interesting gentlemen who were inclined to introspection, also were afflicted with eye-strain and suffered simply for lack of a competent refractionist. Such literary diversions are clever and popular of course, but let us not call them even semi-scientific or attempt to treat them seriously.

CHAPTER IV.

DIVISION III.

REFLEXES TO THE EYE FROM DISTURBANCES IN OTHER PARTS OF THE BODY.

As muscle imbalance may produce reflexes in other parts of the body, so does it seem that, reversing the course of the nerve impressions, functional disturbances or lesions in other parts of the body may, under certain circumstances, cause discomfort or pain in or about the eyes, or even a muscle imbalance. Evidently such ocular symptoms form a part of what has been called "central asthenopia." There is nothing, however, to show that any of these reflexes are "central" in the sense that they are due to changes in the brain. The diagnosis of central asthenopia has heretofore served mainly as a nosological waste-basket into which doubtful cases could be conveniently dumped, often without further thought or trouble—except to the patient. The object in this part of our study is therefore to arrange these cases in some order, first into two large groups and those into smaller ones as they naturally classify themselves. Reflexes to the eye may be manifested by (1) simply the strictly subjective symptoms of imbalance, or (2) an actual imbalance created, or an increase of an imbalance already existing. These two groups should be separated, though they often tend to merge into each other.

Inasmuch as this entire chapter deals with compound imbalance it may seem out of place to consider here the cases of this first group in which sometimes no trace of compound or even of simple imbalance can be detected. But as this group does include the *symptoms* of imbalance, and as

these are usually such as belong to the compound form, it is desirable to glance at them at this point, if only for the purpose of differential diagnosis.

CHAPTER IV.

DIVISION III.

SUBDIVISION I.

Reflexes to the Eye Shown as Symptoms of Imbalance.

Most of the reflexes in or about the eyes are due, as stated at first, to disturbances of function or to lesions occurring in some other part of the body. First, however, it is well to observe the reflexes from one lesion which is near to the globe. These are:

§ 1. **Symptoms of Imbalance from Conjunctivitis.**— It is well known that when a marked conjunctivitis is contracted by a person with hitherto normal eyes, he often experiences the cardinal symptoms of imbalance, and other attending symptoms. If such a person has even a hyperæmia of the conjunctiva, he may also experience the cardinal symptoms of imbalance, although exact tests show that he has practically none, or if any exists, it is at least no worse than it was before. This condition is one which is well recognized and often met with (B 1216).

De Schweinitz has recently called attention to it in a short but excellent article (B 1217). He lays special stress upon the production of asthenopic symptoms by conjunctivitis and calls this condition very aptly "the mimicry of eye-strain." Moreover, he shows that when these cases are treated simply with astringents the symptoms of eye-strain entirely disappear. In a word, we must not allow our knowledge of refraction or of muscle imbalance to make us forget that these symptoms may be the *result* of a simple conjunctivitis and are to be treated as such. As these symptoms of imbalance are, without doubt, more common in America than elsewhere, and as they are sometimes due only to a conjunctivitis, the question naturally arises whether this last may

not in turn depend on some peculiarity of our American life.

Apparently there is one cause (if only a minor one) which should be taken into account, although it has been already noted—the unusual dryness of the atmosphere of the average American house during the winter. This is not only indicated by the shrinking of the woodwork, so often noticed, but can be easily measured by means of the wet bulb thermometer. This dryness of the air has also been demonstrated (B 1218) to be a cause of the distention of the blood-vessels of the mucous membranes, not only of the respiratory tract, but also of the conjunctiva. As such it undoubtedly tends to cause a low grade of hyperæmia.

Our European colleagues not only appreciate that conjunctivitis produces these symptoms of imbalance but they act upon it constantly in their routine treatment. On the other hand, in this country the conjunctivitis is too often looked upon merely as a result of some muscular difficulty. We are apt to omit altogether the use of astringents and look for causes which are more obscure. The result is that, on the average, our European confrères cure one class of cases, and we cure another. With a little more care on the part of both, the proportion of satisfactory results obtained could be decidedly increased.

§ 2. **Ocular Headaches of Entirely Reflex Character.** —We have already considered headaches which are due (1) to the action of the accessory muscles of accommodation and are therefore *directly* the result of muscle imbalance, and (2) those which are preceded by efforts of the ocular muscles *and* by gastric or other reflexes and seem to be *indirectly* the result of muscle imbalance.

We now come to a third class of headaches. These are not dependent upon muscle imbalance, but may occur when the eyes are absolutely normal, or if an imbalance exists, they may occur when no demand is made upon the ocular muscles. The headaches of this group do, however, follow certain disturbances or accompany those disturbances with sufficient regularity to make it reasonable to conclude that the headaches are the result of a functional disturbance or of distinct lesions in other parts of the body.

Headaches of this kind have long been known, and familiar examples of them are numerous. Thus we have:

(*A*) Ocular headaches from disturbances in the stomach. Many persons in perfect health have noticed that when cold substances are taken into the stomach a feeling of distinct discomfort is noticed in or just above the eyes. This has been called "the ice-cream nerve." Others find that the ingestion of certain substances, usually quite harmless, produces in them distinct pain, which is especially located in or above the eyes. Examples might be multiplied almost indefinitely to show this relation of the gastric condition to headaches. A little later, attention will be called to some of those rare but interesting cases, in which the gastric condition produces not simply reflex symptoms but also a distinct muscle imbalance.

(*B*) Ocular headaches from other disturbances of the intestinal canal. These are not so familiar and probably by no means so numerous as those which accompany abnormal conditions of the stomach. Some of these reflex headaches, however, occur so many hours after the ingestion of certain articles of food that the disturbance which causes the headache probably occurs somewhere in the intestines. There is good reason for believing that, after all, the condition of the liver may be a factor in the causation of some of these headaches.

(*C*) Ocular headaches from imperfect nutrition and from toxæmias. Not all of these headaches have symptoms which entitle them to be called ocular, but a sufficient number do occur to make them familiar to every physician. It will be remembered that at present we are considering only cases in which the *symptoms* of imbalance are produced as a reflex from imperfect nutrition and from the toxæmias. The group of cases in which those conditions do produce a perceptible paresis of the intra- or of the extraocular muscles and therefore a distinct muscle imbalance will be considered in the next subdivision.

Every physician is familiar with headaches, even those referred to the eyes, which occur:

(*a*) In anæmic or chlorotic cases. If an ocular examina-

tion is made, a muscle imbalance may or may not be present. At any rate the physician finds that with the administration of iron, strychnine, and under the influence of outdoor life the patient improves in proportion as a count shows improvement in the condition of the blood. This improvement may be without the use of any glasses. It may happen that an imbalance was present, glasses were prescribed but were not worn, and with a tonic regime the ocular headaches disappeared.

(*b*) Headaches with toxæmias are also familiar. They are very common in certain forms of albuminuria. Physicians who are accustomed to make frequent measurements of the elimination of urea, are familiar with the fact that any decided variation in that respect is apt to be followed by headaches, often of an ocular character, and with cabinet baths, diuretics when indicated, and other appropriate treatment these ocular headaches disappear—and without the assistance of glasses of any kind. There is a large class of still other conditions which are accompanied by headache, often of an ocular character, to which it is impossible even to refer in this brief glance at the subject. Thus in the article on "Headache" in the *Encyclopedia Medica* (B 1220) more than a dozen different causes of headache are given, any one of which could be considered from many aspects. It must suffice to say, in a word, that, taken altogether, headaches of an ocular character are almost as frequently a reflex from some other organ to the eyes as directly or indirectly the result of muscle imbalance.

The importance of these facts to the ophthalmologist can hardly be overestimated. They mean that he must not remain an optician or a refractionist, but must practice medicine. When a patient complains of ocular headache which glasses fail to relieve promptly, it becomes an evident duty to have a reliable examination made of the blood, or of the stomach contents, or to have the urine tested, or if necessary an examination made also of the blood pressure. Until this is done no one can know but that some or all of the symptoms of imbalance are simply reflexes from disturbances in other parts of the body. It will be shown

later that such examinations can be made by the ophthalmologist himself or by an assistant of average intelligence. The patient goes to an ophthalmologist because he expects a more thorough examination than can be obtained from an optician, and unless that is given the ophthalmologist is not honest with his patient or with himself.

§ 3. **Reflexes to the Eye from the Nose.**—It is well known that an irritation of the mucous membrane of the nostril will produce secretion of tears, and if that irritation is long continued a conjunctivitis is established. This is usually, of course, the extension of an inflammation from the nostril through the lacrimal canal. Although we do not know what the sequence is, it is certain that there are occasional cases which indicate that, as a result of a lesion in the nose, we have at least the symptoms of imbalance, and sometimes possibly an actual imbalance produced (B 1226–1228).

§ 4. **Reflexes to the Eye from the Ear.**—As we know that irritation of the auditory canal sometimes produces coughing, so there are occasional cases which indicate that a disease of the middle or even of the outer ear may act as a cause in the production of symptoms of imbalance. However, it is only possible to make cursory mention of these reflexes, which occur only in a small number of cases. The references in the bibliography are sufficient to give a clue which can be followed up by students who may be interested in any of these aspects of the subject (B 1229–1230).

§ 5. **Symptoms of Imbalance after Injury.**—Cases are by no means uncommon in which the cardinal symptoms of imbalance are complained of after an injury, by persons whose eyes before that were apparently perfectly normal. Not unfrequently under such circumstances claims are made for damages. The symptoms may depend upon two causes which are quite distinct. It is possible, on the one hand, that the injury produced such a disturbance of the brain centers as to result in an excessive or an insufficient action of one or more groups of the ocular muscles. Evidently such cases do not belong in the group of cases now under consideration. Or again, we may find, after a severe accident, that no imbalance has been caused directly, or else one

which did exist is perhaps not aggravated, but the injury did produce such disturbances in other organs as to cause pain in the eyes, especially painful accommodation, which did not exist before the accident. Such pain is, therefore, an indirect result of the accident.

§ 6. **Non-Traumatic Nerve Lesions.**—Apparently almost every pathological change either in the brain or in the spinal cord may thus be a cause of the cardinal symptoms of imbalance. In some instances the relation of cause and effect can be traced with considerable distinctness, but in others it is much less apparent, and in some entirely hypothetical. It is evident that the literature of this subject requires considerable revision by the neurologist. As such cases come into his hands first, he has the best opportunity of watching the development of any symptoms similar to those of eye-strain, and noting whether the changes for the better or worse are in proportion to the changing condition of the imbalance, as that is worked out by a painstaking ophthalmologist.

§ 7. **Splanchnoptosis.**—During the last decade the attention of physicians has been especially called to this condition, its characteristic being that part or all of the viscera have changed their position, descending to a point below that which they normally occupy. It is no uncommon thing even in young persons to find that the abdominal walls have relaxed to a considerable extent, and this is considered one of the reasons for the descent of the viscera. It occurs in both sexes, and especially in women as the result of frequent parturition. When such a condition exists, the relations of the solar plexus to the viscera which usually cover it are changed, and there follows a neurasthenic condition of a very marked type. One of the earlier manifestations of this is a loss of muscular tone. As this occurs in other portions of the body, so it does in the ocular muscles. Not only the symptoms of imbalance, but imbalance itself results, and we have eye symptoms, usually of a severe and obstinate type.

CHAPTER IV.

DIVISION III.

SUBDIVISION II.

Reflexes to the Eye from Imperfect Nutrition, Intoxications, etc., Shown as Actual Muscle Imbalance.

In this subdivision we wish to consider those rather unusual cases in which a distinct imbalance is produced by imperfect nutrition, intoxication, or by some disturbance of function in another part of the body. In doing this we will consider:

(*A*) Imbalance from imperfect nutrition. As we have seen in the last subdivision, § 2 (*C*), that imperfect nutrition can produce the symptoms of imbalance, so when we study these cases more carefully we find among them a small number in which imbalance itself is without doubt produced by various forms of anæmia (B 1231–1233). This is not surprising when we remember the intimate relation between the blood supply and muscle action in any part of the body (B 1234). Apparently also not simply the constituents of the blood but the degree of blood pressure can affect muscular action, and the question of its effect on the ocular muscles forms an interesting field for investigation (B 1235).

(*B*) Imbalance from disturbances of digestion or from auto-intoxication. De Schweinitz (B 1239) says: "I have seen several cases of unexplained paresis of accommodation apparently follow the ingestion of foodstuffs—that is to say, the ingestion of food which was not in any sense tainted, and doubtless all of us can recall similar examples in our practice." He also cites a case of Thomas', the patient being a young man "who always, an hour after food was taken, suffered from paresis of accommodation." Elschnig (B 1238) mentions several cases in which a similar paresis occurred. It is well known that the ptomaines, especially such as accompany the ingestion of pork, are followed by temporary paralyses not only of the intraocular but of the extraocular muscles (B 1236–1237). In this connection men-

tion might be made of the well-known effects of alcohol in producing a temporary paresis of the extraocular muscles with consequent double vision, or attention might be called to the action of various drugs which are known to produce muscle imbalance. These effects are also "reflexes" in a certain sense, but as the substances are usually classed among the poisons, they will be referred to in the part of our study which deals more directly with the paralyses.

(*C*) The paralyses of the ocular muscles which follow influenza are well known, although their effect is so transitory as to produce often only a slight imbalance (B 1240–1242).

(*D*) It is by no means an uncommon experience to find that the accommodation is altered sometimes rapidly in cases of polyuria and of glycosuria (B 1243–1248). In some of these cases it is probable that the symptoms are referable to changes in the lens, but in many there is distinct paresis of the accommodation or some other form of muscle imbalance.

(*E*) It is also certain that prolonged lactation can affect the intraocular muscles (B 1250–1252), and apparently certain uterine conditions are also occasionally accompanied by imperfect innervation of the ocular muscles.

In a word, it is probable that a more careful study of what we call imperfect nutrition and auto-intoxications in their relation to imbalance would furnish fruitful results. As Elschnig says in the first sentence of one of his recent articles (B 1238), this subject is new and has not yet been worked out.

CHAPTER IV.

DIVISION IV.

TREATMENT OF COMPOUND IMBALANCE.

SUBDIVISION I.

Local Treatment.

§ 1. **Optical Principles Involved.**—If a satisfactory presentation has been made thus far of the different phases of imbalance—especially of the part relating to simple imbalance—comparatively little need be said about the treatment of compound imbalance. The local treatment evidently depends upon the different forms of simple imbalance which combine in each case to produce the compound imbalance. At this point therefore it is only necessary to refer briefly to a few fundamental principles already familiar.

(*A*) It is desirable to correct any intraocular imbalance as exactly as possible.

(*B*) In the correction of any imbalance of the extraocular muscles by prisms or by decentered lenses, temporary relief, at least, is afforded by placing the prisms or decentered lenses in such a position as to favor the affected muscle. Usually, however, it is preferable to turn the prism in the opposite direction if the best ultimate results are desired.

(*C*) In associated compound imbalance, if we correct the function or feature of the imbalance which is the most important, then muscle balance or at least improvement often follows. Thus, over-correction of any existing hypermetropia or persistent use of a cycloplegic helps to relieve an esophoria, or the opposite plan of treatment may assist the opposite condition.

(*D*) In some cases of associated, and in nearly all cases

of dissociated, compound imbalance, it is necessary to deal with each component function or feature of the imbalance, according to the plans outlined in our study of simple imbalance.

Without calling attention to other fundamental principles which are equally well known, the local treatment of compound imbalance can be made clear by a few illustrations.

First, let us consider a typical case of associated imbalance of the excessive type, such as is seen in Fig. 25. Inasmuch as spasm of the accommodation, however slight, is usually the most important feature in such a case, we prescribe only convex glasses, and prisms are seldom necessary. In a case like Fig. 26 with marked esophoria, prisms are usually necessary and perhaps convex glasses also.

Or suppose we have an associated compound imbalance of the insufficient type, as seen in Fig. 27. Here we treat, as best we can, the insufficient accommodation, or if necessary the insufficient convergence. These are, of course, examples of associated compound imbalance.

If we now turn to dissociated forms of compound imbalance, the plan of treatment must be somewhat different. With these we cannot apply the principle that the correction of the most important feature of the imbalance gives relief as far as other features also are concerned.

On the contrary, we are usually obliged to correct, as well as we can, each of the different simple forms which make up the compound imbalance. Unfortunately, it frequently happens that although we suspect which is the most important feature in a given case, and although we attempt to correct it, the patient returns with the same complaints. Under such circumstances it is particularly satisfactory to have an exact record, or even some diagram which shows at a glance just what the imperfection is, and about what is its degree. In this way we are not simply refractionists studying ametropia alone, but we take a more comprehensive view of the component parts of the case.

It is evident that the ability of the practitioner to form a clear conception of the different forms of imbalance entering into any case depends largely upon his knowledge of the

anatomy and physiology of the ocular muscles, and upon his patience and his skill.

§ 2. **How Glasses should be Prescribed.**—A word should be added concerning the glasses themselves. It is one thing to know theoretically what these glasses should be, and quite a different thing for the patient to obtain them. A pair of lenses improperly centered or tipped in the wrong direction, or frames which are uncomfortable, may cause the patient as much annoyance as the eye-strain which it is the effort of the practitioner to relieve. Nevertheless, many of us have been in the habit of writing simply the numbers of the glasses which the patient required, expecting the optician to supply exactly what was desired. This was not an intentional oversight in prescribing, but until recently there were no methods simple, convenient, and fairly accurate by which the necessary measurements could be made.

We need first to agree upon certain data as a basis for measurements for the glasses, and, second, we need trial frames so constructed that these measurements can be made promptly and with sufficient exactness for practical purposes.

First, as to the starting points. If we imagine a vertical plane, parallel to a line joining the center of motion of each eye (the base line) and far enough in front of that line to be beyond the tips of the eyelashes, evidently a pair of well adjusted glasses intended for distant vision would be in that plane. If this plane is cut by a horizontal plane which passes through the base line, the line of intersection of these two planes would lie in the lenses. We might call this the line between the lenses, or simply *the lens line*. For practical purposes, measurements of the height of the nose piece (called height of the bridge) are counted from this line. It is more exact, and also more convenient, for some purposes, to imagine this lens line bisected. Its central point is really the one from which measurements of the height of the bridge are or should be counted. This we may call *the middle point*. Usually this point lies in the nose practically in the division between the two nostrils. Sometimes the middle point corresponds with what is known as the bridge of the nose, and occasionally the point is above the nose.

With this understanding as to a point from which to measure laterally or vertically, we are better prepared to understand the position which the glasses should occupy, and to give measurements for the optician to follow.

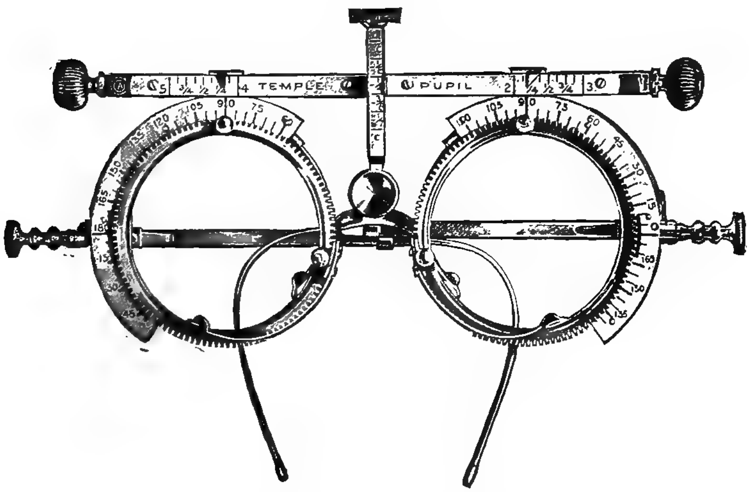

FIG. 35.—Trial frame. American Optical Company model.

During the last few years several optical firms have manufactured trial frames of such completeness of detail that it is possible to use these in taking all the measurements for prescribing glasses. A pair of these frames is seen in Fig. 35. In order to use them for this purpose, we remove the glasses which were employed to test the refraction or the condition of the muscles, and place instead, before each eye, a plane glass which has drawn upon it a vertical and a horizontal line crossing each other at the center of the circular frame (Fig. 36.) It is desirable to determine:

(*A*) The pupillary distance. It might be supposed that for this we would make use of some one of the visuometers described in the first volume. While they are excellent, especially when high degrees of ametropia exist and for some other clinical purposes, or for all laboratory methods, such exact measurements are usually unnecessary in the routine of every-day work. The test frames are simpler.

We merely turn the thumb-screw at either end of the frame, and the eye of the observer being directly opposite first one and then the other eye of the patient, we notice the point at which the vertical line drawn on the plane glass passes apparently through the center of the pupil. On the horizontal bar of all of the modern test frames there is a scale with an index showing the distance which the centers of the circles are from each other. This is therefore read off on the scale and we have at once the pupillary distance.

(*B*) To determine the height of the bridge of the nose. The modern test frames have also a short vertical bar extending downward from the center of the horizontal bar of the frame. This vertical bar, which terminates below in an arc to rest on the nose, has a scale marked on it, and can be elevated or depressed by a thumb-screw. When the portion which rests on the nose is on the same horizontal line as the center of the glass before each eye, the vertical scale registers zero. In that case, of course, the point on the nose corresponds to what we have called the middle point. If the level of the centers of the glasses is below the bridge of the nose as is usual, or above it, that is read off on the vertical scale.

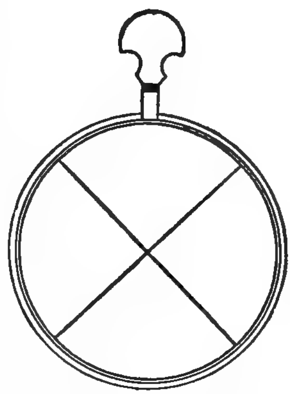

FIG. 36.—Plane glass for test frame.

(*C*) We wish to ascertain also whether the bridge of the nose is anterior or posterior to the middle point. That is measured by a short and delicate fore and aft bar and indicated on a scale placed horizontally.

(*D*) To determine the width of the nose at the point where it would naturally be grasped by a pair of eye-glasses or spectacles, it is usually sufficient to sight over a millimeter measure held horizontally just in front of the nose. We can obtain this width more exactly, however, by measuring it with a pair of delicate callipers made for the purpose, or by

bending over the nose a bit of lead wire and measuring the curve thus obtained.

(*E*) The angle at which the upper edge of a reading-glass is tipped forward should also be kept for record and for guidance of the optician. Unfortunately none of the trial frames are as yet made with an arc to show the amount of this tipping, although such an addition could undoubtedly be made without difficulty. Usually it is sufficient to note that the glass should be tipped forward at an angle of five, ten, or more degrees as desired. This is ordinarily estimated by the optician. Practically, however, a few degrees makes but little difference in the refractive power, if weak glasses are used.

(*F*) It is desirable to mention the width of the frame. Ordinarily the optician adds about two inches to the pupillary distance and counts that as the ends of the frames. When spectacles are desired, a note should be made of the form and length of the side piece or temple.

(*G*) The size of the lens itself can usually be left with the optician, although it is worth while to remember that in the trade the smallest oval, the one usually worn by children, is known as a 2-eye. The next larger size is 1 eye, then comes 0 eye, which is the size used in most spectacles for adults. This one measures 37 millimeters in its long diameter. The 00 eye is less frequently worn.

Toric lenses have such decided advantages over those of the ordinary form, and are now made even with astigmatic combinations at such reasonable rates, that patients often prefer glasses ground in that form. Those who use bifocals with the lower segment fused to the upper one, are generally well satisfied with that arrangement.

(*H*) Finally, patients to whom economy is of importance find it convenient to know, at least approximately, the relative cost of frames of gold, nickle, or other material. If their preference is also noted on the prescription blank, it saves them embarrassment and sometimes protects them from unscrupulous vendors.

CHAPTER IV.

DIVISION IV.

SUBDIVISION II.

The Recognition and Treatment of General Causes of Imbalance.

In the preceding studies of imbalance, frequent references have been made to the relation of these abnormal conditions to the "general system" or the "general health." It seems proper, therefore, at this point to call attention to the facility with which certain measurements can be made of some of these factors which are intimately related to the general health. The reasons for this are:

First. The tests require only a comparatively small outfit in the way of apparatus and reagents.

Second. Books upon the subject are abundant and the procedures for making the tests can be readily learned.

Third. The data obtained in this way are of decided importance.

§ 1. **Anæmia and Tests of the Blood.**—The special reasons for making such tests in cases of suspected anæmia are:

First, that we may have some accurate measure as to how important a factor the anæmia is in that individual case, and second, that we may know later whether or not the form of iron or other tonic which has been prescribed is in reality producing the change in the character of the blood which we desire.

Perhaps the most simple and practical method of estimating the percentage of the hæmoglobin is by means of the Tallquist scale. With this it is only necessary to prick the ear or the finger, allow a few drops to be absorbed on a bit of paper prepared for that purpose, and then compare the shade of the red spot thus produced with certain red test bands.

The method is certainly very rapid, requiring only two or three minutes and practically no skill. Some of the most recent text-books on the blood speak of this method as giving excellent results, although it has the disadvantage that the comparison of colors can be made only by daylight.

In the well-known Gower's test we have only to make a solution of the blood of a certain known strength and compare the color which is thus obtained with that of a standard tube furnished for the purpose. The methods of Fleischel and of Henoque are undoubtedly more accurate, but they require an amount of skill and time which is seldom granted to the practicing ophthalmologist. As a measurement of the amount of hæmoglobin can, however, be made easily, with the Tallquist scale, there seems no excuse for an off-hand diagnosis of anæmia, when it may not be present. A test of the percentage of the hæmoglobin should be a part of the complete examination of an anæmic patient as much as the test of the muscle balance. Many require iron, cod-liver oil, and the advantages of general muscle exercise, quite as much as they require a correction of the ocular muscle imbalance.

§ 2. **Autointoxication and Tests of the Urine.**—It is a familiar fact that whenever the normal elimination of the waste products of the system is impeded in any way, we find morbid processes developing in different portions of the body. This is so well known to the ophthalmologist, that tests for albumin in the urine become a routine part of the examination in certain diseases of the retina, just as tests for sugar become a part of the examination in many cases of cataract. In imbalance the question often arises whether there is proper elimination of urea, and to determine that of course we must have a quantitative test from a twenty-four-hour sample.

The ophthalmologist may imagine that these quantitative analyses are inconvenient or practically impossible to him. But that is by no means ordinarily the case. The apparatus necessary for this purpose is simple and inexpensive, although it is essential to have a good ureometer.

It is out of place here to go into details concerning the bromine or other test for urea; suffice it to say that a test which is quite accurate can be made by any practitioner or even by his assistant, in a few minutes. It is impossible also to discuss the bearing of any such data, but it is evident that when we do find an imperfect elimination of urea associated

with imbalance of the ocular muscles, especially of the insufficient associated type, the use of cabinet baths and other means which tend to better elimination form a very important and often a necessary part of the treatment.

§ 3. **Autointoxications—Especially with Sick Headaches, and Tests of the Stomach Contents.**—As we know that certain forms of muscle imbalance not infrequently affect the stomach, and as we also know that abnormal conditions of the stomach are apt to give rise to the symptoms at least, of imbalance, it is evident that if any one pretends to reach an intelligent opinion in a case of imbalance with gastric symptoms—or even without those, if headache is obstinate,—it is necessary to obtain some data as to the condition of the stomach. Otherwise it is only fair to turn the patient over to some one else who can do so.

Those really qualified to give expert opinions concerning gastric conditions are comparatively few; they are in large cities, and a consultation with them often involves considerable expense and inconvenience to the patient. In practically all such cases the important thing to be done is to give a test meal, and make a chemical examination of the stomach contents. This is not always done by the consultant himself, but is often left to his assistant. The point to which attention is called here is simply this: the ophthalmologist can make these examinations himself or have them made by his own assistant, and the data thus obtained are usually quite sufficient for this purpose. This is not a theory, but the result of a comparison of tests made personally and also by an assistant, with results obtained by those who are accustomed to such work. As this is perhaps an innovation, a word of explanation may be necessary.

(*A*) The apparatus and chemicals necessary for such tests are also quite simple and inexpensive. Several of the manufacturing chemical firms furnish sets of these for ten or fifteen dollars. Books on examination of the stomach contents are numerous. Some are elaborate and confusing, others are not sufficiently explicit for the needs of the beginner in such work. If, however, the ophthalmologist desires to inform himself on this point, he can go to some library where

he can look over the references in the bibliography or other books which are more recent and better, and can easily select what is best suited to his needs. As soon as he is interested in the subject, one author will not suffice, as the desire for more intelligent opinions of this kind leads to more exact work.

(*B*) The manipulation is comparatively easy for the ophthalmologist. Any one who is accustomed to surgical procedures or who has learned to use the ophthalmoscope, or the tests for color blindness, can also learn to manipulate the stomach tube, the burette, and can judge of changes in the colors when titrations are made.

(*C*) The few important tests are neither complicated nor numerous. With the usual training in chemistry one can understand the reactions at least as well as they are understood by the ordinary gastrologist, though of course it is not pretended that either he or the ophthalmologist can make such an examination with anything like the exactness of the professional chemist.

The question which we ask ourselves first is concerning the total acidity. While it is true the degree of acidity in itself may not mean very much, considering the very decided variations in this respect in different individuals, still when the acidity is taken in connection with other facts, and certainly if there are decided variations in that individual at different times, this is at least very suggestive to the ophthalmologist.

Of course it is beyond the scope of a study of the muscles of the eye to enter into details of this or any similar chemical tests. It is, however, proper to observe how simple most of these are, especially the important ones.

If the manipulator does his work with exactness, if his glassware is religiously clean, if the deci-normal alkali solution has not been contaminated, it is only necessary to dilute the stomach contents according to the directions given, make his titrations, and he has the result promptly.

The tests for hydrochloric acid are equally simple, and the determination of the free hydrocholoric acid can be done without difficulty, as also the determination of the combined

chlorine. These and a few other details are sufficient for the formation of at least some opinion as to whether the stomach is in normal or abnormal condition.

§ 4. **Headaches and Other Symptoms of Imbalance, and Tests of the Blood Pressure.** — Although we have long known that the blood pressure is a delicate index of the presence of certain morbid conditions, especially of the kidneys, and although we have known also that the pressure varies promptly and very decidedly with impressions made upon the nervous system, still these facts have belonged rather to the realm of laboratory experiment. During the last decade, however, very decided improvements have been made in clinical methods for determining the degree of the blood pressure, and henceforth appliances for measuring this must be counted as essential in the armamentarium of every well qualified physician.

The point is, that the ophthalmologist should be prepared to make these tests; the appliances for the purposes are simple, the cost ranging from six or eight dollars or upward, according to the complexity of instruments used; text-books upon the subject are numerous, and the methods easily learned. As the number and importance of clinical data will increase probably more rapidly than concerning other subjects, reference is made in the bibliography to only a few of the books which are more prominent now. Later study may prove that the relation of blood pressure to the ocular muscles is not of as much importance as it now appears, but none the less the subject is one of too much possible value not to receive at least passing notice.

From all the foregoing we are apparently warranted in the conclusion that the three statements made in the first part of this subdivision are fully justified by the facts. The practical importance of this conclusion can hardly be overestimated in its relation to the general treatment of imbalance, especially compound imbalance. It means not simply that the ophthalmologist should practice medicine in the broad sense of that term, but moreover that he can do so without much extra effort, and with decided advantage to his patients and credit to himself.

CHAPTER IV.

DIVISION IV.

SUBDIVISION III.

Simple Forms of Gymnastic Exercise.

In the first volume attention was called to the relation which often exists between the condition of the muscular system as a whole and the ocular muscles. The daily experience of the ophthalmologist teaches him that the complaints of persons who suffer from imbalance of the ocular muscles are usually augmented when the condition of the general muscular system is imperfect, and diminished when that condition is improved. Therefore it is desirable to find some form of exercise which is simple, inexpensive, and always available. These desiderata seem to be met by the systematic movements described by Dr. Sargent, Director of the Hemenway Gymnasium at Harvard. Although they have long been known, they have been elaborated so thoroughly by him that it is convenient to call them collectively "Sargent's Method." They were referred to briefly in an earlier part of our study (Vol. I, p. 373) but as we were then dealing only with physiological actions, it was unnecessary to enter into details which are particularly suited to pathological conditions. At this point therefore we may ask more exactly what some of these exercises are, and how they serve the double purpose as a test of strength and also a means for improving it.

To illustrate, let us suppose that we wish to test the strength of an individual who weighs 150 pounds, who is five feet and a half high, and whose arms are 21 inches long.

First, suppose he lies flat on his back on the floor with the fingers touching the tops of the shoulders, and the feet under a lounge or strap or other object which will act as a counterweight and hold the feet in place (Fig. 37). He then lifts the body until the tips of the elbows touch the knees. In doing so, practically half of the body is lifted. Multiply one half of the weight of the body (75) by one half of the total height in feet (2.75), and this again by the number of times

the exercise can be repeated within a certain time, say half an hour. If that is 75 times, we have 15,468 as the number of foot-pounds lifted by that group of muscles in that time.

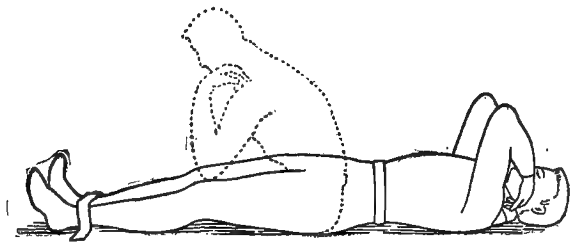

FIG. 37.—Exercise No. 1, "Elbows to knees."

Or another set of muscles may be brought into play in an equally simple manner. Thus suppose this person lies

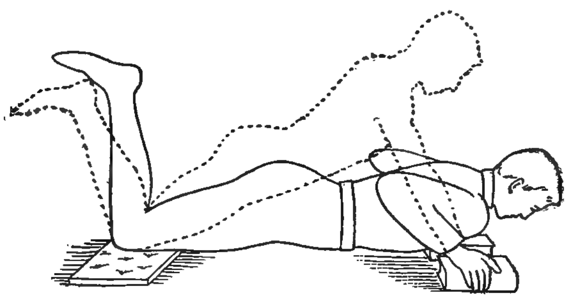

FIG. 38.—Exercise No. 2, "Push up."

with his face downward (Fig. 38), the legs bent, and each hand resting on a book or some other object as a support. Then suppose the body is lifted by extending the arms. This time we multiply one half the weight of the body in pounds by the length of the arm in feet, multiply this product by the number of times the body can be thus lifted in a given time,—for example, fifty in half an hour. That gives 6562 as the number of foot-pounds lifted by that set of muscles in that time.

Or let the person bend down until the tips of the fingers touch the floor between his feet, then straightening up, raise the body and arms at the same time (Fig. 39). Again multiply one-half the total weight (75) by one-half the total

height (2.75), this product by the number of times the exercise is accomplished in a given time. If it is seventy-five in half an hour we have 15,468 as the number of foot-pounds lifted by that set of muscles in that time.

Or finally let the individual, standing on his toes, flex the knees until the buttocks rest upon the heels or nearly so, and as a balance let the arms be extended horizontally. Then rise to a standing position, bringing the arms across the

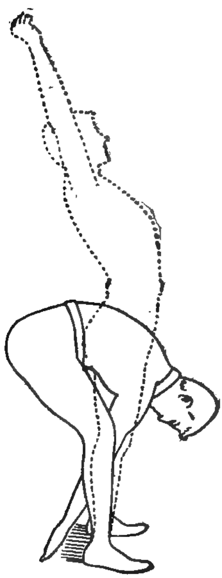

FIG. 39.—Exercise No. 3, "Fingers to floor."

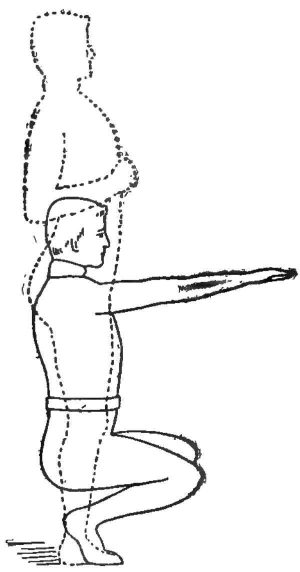

FIG. 40.—Exercise No. 4, "Rise on toes."

chest (Fig. 40). In doing this the entire trunk is raised. To find the expression in figures of the force exerted, we multiply the total weight (150) by one-half the height (2.75), that by the number of times the body is lifted, say thirty in half an hour, and we have 12,375, the number of foot-pounds lifted by that set of muscles in that time. When these data are arranged in tabular form we see the total number of foot-pounds lifted in half an hour. Thus—

Form of Exercise	Weight Lifted		Height Lifted		Times Lifted	Foot-Pounds
1st. Abdomen	75 lb.	x	2.75 feet	x	75	15,468
2d. Chest and arms	75 lb.	x	1.75 feet	x	50	6,562
3d. Back	75 lb.	x	2.75 feet	x	75	15,468
4th. Thighs	150 lb.	x	2.75 feet	x	30	12,375
						49,873

It is possible, of course, to vary these exercises or to add to them almost indefinitely, but these four are chosen as good examples, and when they are performed, no matter in what order, but all within a certain definite time—half an hour, for example,—they give a very fair approximation of the strength of that individual expressed in foot-pounds lifted within that time.

We have already noticed that the strength of the average healthy man is equal to about forty-five to fifty thousand foot-pounds in half an hour, though it may be made much larger by exercise, and is smaller of course in women and children.

These exercises can be easily learned by most persons if the idea is simply given to them, or by a glance at such illustrations. As these gymnastics are often of much value to neurotic women, it has been found desirable to have some instructor, preferably a woman, learn the methods thoroughly, not only the four exercises which are here given for illustration, but others similar to them which have been described by Sargent (B 824). When such a patient comes for directions, it is well to send her to an instructor who will teach her the exercises. Moreover, it is often of advantage to have them repeated and elaborated day after day, under the direction of some one who will make sure that they are not done in the desultory and slipshod fashion with which such patients are accustomed to follow most methods of treatment. The increase in the strength, of which the patient can also easily convince himself, is always a source of encouragement.

CHAPTER IV.

DIVISION IV.

SUBDIVISION IV.

The Optical Treatment of Muscle Imbalance by the Optician or by the Ophthalmologist.

A chapter on muscle imbalance in a modern treatise is incomplete without some mention of its treatment by the optician and by the ophthalmologist respectively.

It is desirable first to agree on what we mean by these terms. An optician is often defined as "one who makes and sells glasses." Formerly that was his sole duty, but modern machinery gives constantly less for his hands and leaves more for his brain to do. An optician is also defined as "one skilled in optics." In recent years that is his ambition, and the more intelligent tend to achieve that, in spite of any short-sighted opposition. They have the right to learn all they can for trade purposes of refraction, of imbalance, of the ophthalmometer, the ophthalmoscope, or any similar instrument of precision. Nor is there any law to prevent their using such instruments on persons who are willing to submit to the examinations. The optician, however, can not honestly pretend to know anything of medicine or surgery.

The ophthalmologist, on the other hand, is expected to be also "one skilled in optics," and in addition to have a thorough acquaintance with and a legal right to practise medicine and surgery.

The point is that if each of these classes of workers is true to its ideals, and honest to the public, the two fields of activity will prove quite distinct. It will be admitted probably by every one that:

(*A*) Cases of simple imbalance occurring in the form of low or moderate degrees of hypermetropia, low degrees of myopia and of astigmatism, and most cases of presbyopia can be tested and provided with glasses by a competent optician with great convenience and economy and usually with-

out much risk. Of late years the optician has done this, and probably he will continue to do so more and more. The more accuracy and skill he acquires in his craft the better for himself, for the public, and for the ophthalmologist. Probably one pair of glasses on the average will be worn sooner or later by every one of the millions of inhabitants of this and other enlightened countries, and the sale of these, with their various changes and repairing, would seem to be sufficient occupation for one class of workers, provided they do that well.

(*B*) The fitting of glasses by an optician, even in some of the cases included in the above list, is accompanied with certain risks.

(*a*) When hypermetropia occurs in an anæmic person who complains of headache, it is impossible to determine, without a suitable medical examination or chemical tests, whether these headaches are due to hypermetropia or to some defect of digestion, nutrition, or elimination.

(*b*) When an apparent presbyopia is rapidly increasing, it is impossible to determine, without such a suitable medical examination or by chemical tests, whether the changing vision is due simply to presbyopia or to an incipient glaucoma, or to a toxæmia, albuminuria, glycosuria, or to some other serious condition. If such a cause is discovered in time and proper treatment instituted there is a chance for recovery. Delay may cost a patient his sight or his life.

(*C*) In the cases of ametropia which are not included under (*A*) the danger of some decrease of vision is so real, especially as years advance, that the one who gives glasses to such persons assumes no small responsibility.

(*D*) In cases of imbalance which are not due primarily to ametropia but to abnormal muscular contractions or relaxations, proper medical examinations will sometimes reveal the ultimate causes of the difficulty when they can not be determined by optical instruments.

(*E*) In the treatment of all cases, the patient has a right to expect that the ophthalmologist shall be not only one skilled in optics, but also that he shall have the skill of a physician and surgeon. If he does not have this skill and

exercise it, he is liable for damages in a suit for malpractice.

(*F*) In like manner if an optician sells glasses for a condition which he knows can not be remedied by them, he is not only guilty of fraud, but may also become liable for damages if injury results to the buyer.

In certain states and in England, optometrists have been recognized by law. But if this means special privileges, it also means corresponding obligations. The courts have not yet decided in test cases whether these laws will prove as acceptable to opticians as many imagine.

Brevity requires these propositions to be stated without any elaboration, but it is probable that they will be generally admitted.

In a word, we find the truth of our proposition, that if each class of workers lives up to its ideals, the respective spheres of activity become more distinct with the growth of this branch of science and with the increasing intelligence of the public.

SUMMARY OF CHAPTER IV.

In this chapter we studied the conditions presented when anomalies exist in two or more groups of muscles. Such cases can be divided into two general groups, the associated and the dissociated, the former being either of the spastic or of the paretic type. The symptoms in each case are such as have been described when dealing with the respective forms of simple imbalance.

The effect of the ocular muscles upon the eye or other portions of the body was considered in some detail. In doing this we examined the effects of the intraocular muscles on intraocular structures, finding these in general well defined, although the supposed effect as a cause of glaucoma or of cataract is still far from settled.

The effects of the extraocular muscles on the globe were found to be very distinct, especially as the recti produce changes in the form of the cornea, or as they influence the intraocular tension.

We saw that the ocular muscles as a whole might be as-

sociated directly with excessive contraction of the occipito-frontalis, this giving rise to headache.

We glanced at the path over which impressions pass from the eye to other parts of the body, and then agreed upon certain criteria by which to determine whether any given symptom is or is not a result of imbalance.

Having determined this, we examined with considerable care the forms of headache and of other nervous conditions which are indirectly the result of muscle imbalance, although some of these effects proved to be more imaginary than real. Attention was called, however, to the necessity of care in the judgments formed concerning these effects, lest exaggerated estimates be made of their number and their importance.

As reflexes pass from the eye to other portions of the body, so we found that reflexes could pass in a similar way from neighboring tissues or from distant organs to the eye, producing only the symptoms of imbalance. Thus a mimicry of eye-strain might result from a simple conjunctivitis, or headaches with ocular symptoms might result from disturbances of the stomach, or be due to imperfect nutrition, to anæmias, or other causes.

Finally we found that not only the symptoms of imbalance, but actual muscle imbalance itself, could be produced from disturbances of digestion or from ptomaines, influenza, prolonged lactation, and from other causes. In most of these cases, the imbalance consists of a slight paresis, usually of the intraocular muscles. These also are in a certain sense what we call reflexes.

With this study of the relation of the ocular muscles to distant parts of the body we were better prepared to consider the treatment of compound imbalance. In this we found it desirable to follow usually the indications which had been already worked out in the study of different forms of simple imbalance. Having decided thus what glasses were theoretically the best, attention was called to a few practical points concerning the manner of prescribing the glasses, in justice to the optician who fills the prescriptions.

As for the constitutional treatment of imbalance, stress was laid upon the necessity of recognizing clearly the underlying

cause in each case, and the manner of improving the general muscular condition by means of systematic exercises.

It may be added that if, as refractionists, we take only ametropia into account our cases are often annoying to the one who treats them and discouraging to the patients. If, however, we regard them from the standpoint of muscle imbalance, they assume a different aspect. Each time it becomes interesting to search out the different factors which combine to produce the compound imbalance in that individual case. The skill and ingenuity of the practitioner are challenged, and as he obtains gradually a clearer insight of the local and general causes, he is able to make a better diagnosis and advise more satisfactory treatment.

PART II.

ACTUAL DEVIATIONS DUE TO LESIONS IN THE EXTRAOCULAR MUSCLES OR IN THE GLOBE.

CHAPTER I.

DEFINITIONS.

§ 1. **The Term "Deviation."**—We now turn to another large group in which the visual axes deviate from the position which they should occupy. This condition may be defined more exactly by saying that when the visual axis of one eye fixes a certain point, the fellow eye is directed to some other point. Evidently this describes an *actual* and *manifest* deviation, as distinguished from forms of heterophoria in which there exists only the *tendency* to a deviation. These actual deviations are usually apparent without any examination, whereas the latent deviations of heterophoria are revealed only by special tests.

As clearness of definition is especially necessary in dealing with a subject in itself unusually obscure, this use of the word "deviation" should be briefly explained. The condition which we are now considering is usually called "strabismus" or "squint," and these terms are still used constantly by some of the best writers. But as we have gradually learned that the convergent form of strabismus or squint is the most frequent, and is often associated with hypermetropia, little by little those terms have grown to

mean to some readers a deviation inward associated with hypermetropia, while to others it means any deviation inward, and to still others, any deviation in any direction. Therefore although it is well to retain these terms "strabismus" and "squint," and to use them as synonymous, it is also well to restrict them to a deviation inward (an esotropia) due to a hypermetropia alone or to a hypermetropia with some other cause.

It is partly to avoid this confusion that the term "heterotropia" has been used of late, especially in America, to describe actual deviations of any kind. That was a step in the direction of clearer definition and therefore of clearer thinking. The word "heterotropia" accords with the rest of our nomenclature describing ocular movements, and its meaning is shown in its composition.

We shall here use "heterotropia" as a synonym for "deviations," but the English term, though cumbersome, will be given preference, especially because the meaning of "deviation" has not been obscured either by tradition or by improper usage.

§ 2. **Relation of Latent to Actual Deviations.**—Actual deviations are usually exaggerated forms of the corresponding variety of latent deviations.

There is, however, one great and essential difference between the latent and the actual—that is, between heterophoria and heterotropia. In the former, the retinal images fall on points which correspond or tend to correspond with each other. As a result, there is a constant effort on the part of the individual to keep the visual axes in the position which they should occupy. This effort is the cause, more or less directly, of the symptoms of eye-strain from which the patient often suffers.

But in actual deviations, especially when one eye has given up the effort to maintain binocular vision, it swings out of place into the position which it can occupy with the most comfort. Ordinarily diplopia follows—temporarily, at least,—or more or less loss of vision.

§ 3. **Deviations are Non-paralytic or Paralytic.**—All actual deviations divide themselves naturally into two great

classes—the ocular or non-paralytic, and the central or paralytic. The reason for this important distinction, if expressed in terms of pathology, is that in the former class the lesion which produces the deviation is in the extraocular muscles or in the globe. In the latter, the lesion is in the brain or in the nerves themselves. Or if we define the reason for the distinction by the effects of the lesion, then we can say that all of these actual deviations are non-paralytic. Those two terms are the most readily understood, and therefore the best for general use. But they describe rather the more evident and well developed types. We shall see that for clinical purposes it is most convenient to designate these two great classes also as active and passive deviations respectively. In this part we are to deal with the ocular, or non-paralytic, or active deviations, understanding that these are also called ocular or non-paralytic or active forms of heterotropia.

CHAPTER II.

SYMPTOMS AND DIAGNOSIS.

DIVISION I.

DEVIATIONS AND THEIR MEASUREMENT.

§ 1. **The importance of measuring the deviation** accurately is generally acknowledged. And yet the fact is, that such measurements are frequently omitted, and after satisfying ourselves with a superficial examination we are frequently ready to express an opinion and proceed to treatment, too often of the operative variety. If more measurements of the degree of deviation were made, and more exact records kept of the results of various forms of treatment, we should the sooner be rid of the confusion in which this subject is involved. The methods of measurements here described apply to non-paralytic and also to paralytic deviations.

§ 2. **A cycloplegic necessary** for exact measurement. It is probable that one frequent and important source of error in measuring these deviations is that the accommodation is allowed to remain active. That is often an error. If a patient with hypermetropic esotropia is asked to fix an object immediately in front, the deviation of the second eye can be made to vary almost as the examiner wishes, by causing the object which is fixed to approach or recede from the fixing eye. This means evidently that if we wish to obtain the most constant results it is desirable to place both eyes under the full effect of a cycloplegic. But measurements should also be made when the fixing eye exerts 1, 2, 3, or 4 diopters of accommodation.

§ 3. **Methods of Measuring the Deviation.**—These may be objective or subjective.

I. Objective methods:

(*A*) The Linear Strabometer. A simple method of estimating very roughly the degree of deviation is to have the patient look with the better eye at some distant object, while the examiner holds a millimeter rule or other measure just beneath the lower lid of the deviating eye, noting the point which is opposite the center of the pupil. Then, if the better eye is closed, and the patient looks at the same object with the previously deviating eye, and if note is made again of the point on the measure opposite the center of the pupil in its new position, the difference between those two points will measure the amount of deviation. This is evidently only a rough estimate of the degree, and a considerable error due to parallax is unavoidable.

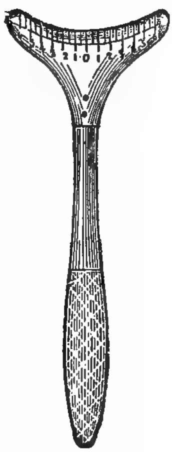

FIG. 41.—Linear strabometer.

In order to make this method a little more exact, the millimeter measure has been cut on an arc, so arranged that it can be conveniently held just at the edge of the lower lid. Fig. 41.

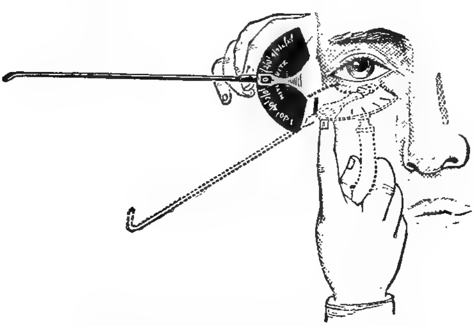

FIG. 42.—Strabometer of the author.

(*B*) Strabometer of the author. In view of the disadvantages of the ordinary strabometer, I had one made such as is seen in Fig. 42. Its general plan is similar to that of Dana's pocket perimeter. It consists of a "sector difference" cut from a thin sheet of brass. The inner arc has a radius of fifteen millimeters, and the outer one a radius of about forty millimeters. The edge of the larger circle is graduated in degrees from

zero in the center to about sixty. A handle, bent to fit the curvature of the face, is attached near the center of the surface which is not graduated.

Over the graduated surface there is fitted a strip of thin brass like a flattened radius. Near the outer edge of the disc this strip has an opening, with an index mark on it. The protruding end of the strip is extended into a small but firm wire, fifteen centimeters long. Near each end of the wire there is a vertical off-set some ten millimeters high, the two together forming a gun-sight.

To illustrate the use of this strabometer, let us suppose that we wish to measure a divergence of the left eye. The patient first closes the right eye and with the left fixes a distant object directly in front. The surgeon then rests the arc of the smaller circle gently against the lower lid near its margin. As the center of motion of most globes is about thirteen or fourteen millimeters behind the cornea, and as the lid is perhaps two millimeters thick, therefore the center of curvature of the arcs corresponds practically with the center of motion of the globe.

It is necessary first to make sure that the zero point is in the right position. Therefore, while the left eye is still looking straight ahead, the surgeon moves the index mark of the gun-sight to zero of the arc, and, sighting across the projecting points, assures himself that the zero point is in line with the center of the pupil. The right eye is then uncovered, and as that one fixes in turn the distant object, the left eye swings outward. Meanwhile, the surgeon, being careful to hold the arc of the strabometer in the same position, slides the gun-sight over the arc, sighting across the projecting points, until it is brought just beneath the center of the pupil of the eye, which is in its divergent position. It is only necessary then to read off on the arc the number of degrees of the deviation. This instrument, although used as a strabometer, may, with certain evident slight modifications, serve as a perimeter more accurately than the original model. By making the long projecting wire adjustable, the whole instrument may be carried in the pocket.

(*C*) The corneal reflexes. Measurements with these are

numerous and varied. Some are mere approximations, others quite exact. The principle on which they depend has already been considered in connection with measurements of the angle alpha. (Vol. I, p. 130.) It means practically that when the light from a candle, or, as usual, from an ophthalmoscope, is thrown upon the cornea, the reflection should be seen in the center of each pupil, if both visual axes are in the primary position. But when one eye deviates from the position which it should occupy, the malposition of the reflection is seen at once. This is a simple and rapid method, but not the most accurate.

(*a*) Hirschberg's method. His plan was to place a lighted candle in front of the patient's face, and, while the observer looks over the candle, to notice the position of the reflection on each cornea. He estimated that, as the cornea is about twelve millimeters in diameter, therefore, when the reflection is seen in the center of one and at the edge of the other cornea (namely, with a deviation of six millimeters), that amount subtends an angle of about forty-five degrees. Of course the nearer the reflection from the squinting eye is to the center of the pupil, the less in proportion will be the number of degrees of the arc of deviation.

(*b*) Maddox's modifications. This method has been elaborated to a considerable degree by Maddox (B 1330), as already described (Vol. I, p. 129).

(*D*) Javal's method. The foregoing simple methods are excellent for rough estimation of the amount of deviation, but if we wish to be exact we must make use of a graduated arc. For this purpose the perimeter suggests itself, and with it two plans of procedure may be adopted. The simpler and more exact is the one suggested by Javal (B 1313).

This consists in placing the deviating eye at the center of the arc, having the patient fix a distant object with the better eye, and then, moving a light along the arc of the perimeter, observing the point on it at which the corneal reflection is directly in the center of the pupil of the squinting eye. It is probable that this method would have been used much more frequently—indeed, almost exclusively—but for the error due to the fact that, with the light only on the arc, the

observer does not know at any time whether his own eye is in the line of the axis of vision of the observed eye. But when the perimeter has a gun-sight or telescope attachment (Vol. I, pp. 190–191) the results are much more constant.

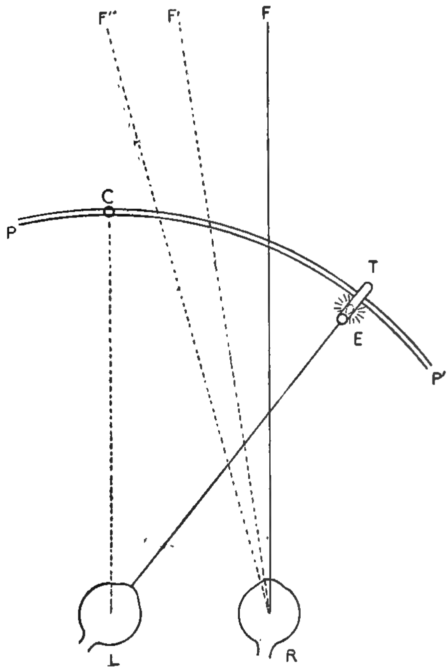

FIG. 43.—Javal's method of measuring the deviations. With the perimeter of the author.

(*E*) Charpentier's method. The same thing is accomplished in a little different way by Charpentier's method. The head is arranged in the same manner, the deviating eye being at the center of the arc, but in this instance the light remains at the zero point of the arc. The surgeon then sights along the arc at different points until he sees the reflex just in the center of the pupil. Inasmuch as the angle of reflection is equal to the angle of incidence, the real amount of deviation of the eye is half of the arc between the source of light and the telescope (E H). A very convenient appliance with which to make this measurement has been suggested by de Wecker (B 1333). As untrained patients will not always keep the good eye directed at a distant object or immediately in front, de Wecker placed a small mirror just within the arc, in such a position that it is easy for the patient to look at the image of his own eye while the reflection of the candle flame or of the electric light on the squinting eye is observed by the surgeon.

(*F*) Measurement with the flattened perimeter. Instead of counting directly in degrees, the arc is sometimes flattened

out, as it were, and the measure is taken instead on a tangent scale with a radius of convenient length. As these scales are often figured and are of decided practical value, the figures are given here for the construction of one of the usual form—that is, with a radius of one meter.

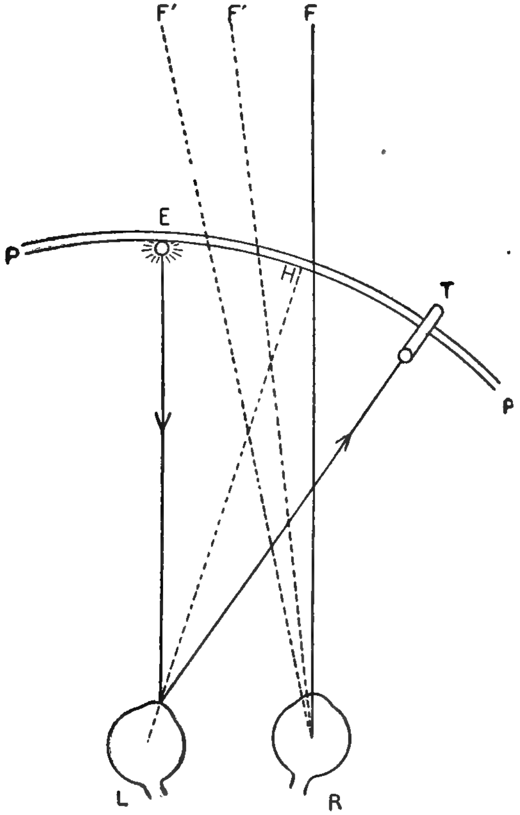

FIG. 44—Charpentier's method of measuring the deviations. With the perimeter of the author.

A zero point is placed in the center of a board about 15 cm. wide and a little more than 2 m. long. On each side of this point we mark off the degrees in centimeters, as these are obtained from a table of natural tangents.

In a circle with a radius of one meter the size of the arc in proportion to the tangent is as follows :

Arc-Tangent	Arc-Tangent	Arc-Tangent	Arc-Tangent	Arc-Tangent
1°= 1.7 cm.	10°=17.6 cm.	19°=34.4 cm.	28°=53.1 cm.	37°= 75.3 cm.
2°= 3.4 cm.	11°=19.4 cm.	20°=36.4 cm.	29°=55.4 cm.	38°= 78.1 cm.
3°= 5.2 cm.	12°=21.2 cm.	21°=38.3 cm.	30°=57.7 cm.	39°= 80.9 cm.
4°= 6.9 cm.	13°=23.0 cm.	22°=40.4 cm.	31°=60.0 cm.	40°= 83.9 cm.
5°= 8.7 cm.	14°=24.9 cm.	23°=42.4 cm.	32°=62.4 cm.	41°= 86.9 cm.
6°=10.5 cm.	15°=26.7 cm.	24°=44.5 cm.	33°=64.9 cm.	42°= 90.0 cm.
7°=12.2 cm.	16°=28.6 cm.	25°=46.6 cm.	34°=67.4 cm.	43°= 93.2 cm.
8°=14.0 cm.	17°=30.5 cm.	26°=48.7 cm.	35°=70.0 cm.	44°= 96.5 cm.
9°=15.8 cm.	18°=32.4 cm.	27°=50.9 cm.	36°=72.6 cm.	45°=100.0 cm.

As each degree cannot be marked with figures large enough to be seen by the patient at a distance of one meter, it is better to place a large figure over each fifth degree, and dots between.

In order to use the flattened perimeter for determining objectively the amount of deviation, the surgeon first meas-

FIG. 45.—The objective measurement with the flattened perimeter of an esotropia of the left eye.

ures the distance from the center of the board to the face of the patient, as can be done conveniently by a string attached to the center of the board. The patient then looks with his fixing eye at the zero point on the board, while the examiner slides a light along the board toward the point to which

the visual axis of the deviating eye is directed. Then, if the head of the examiner is kept a little lower than a line passing from the light to the deviating eye, and about in range with that line, it is possible to slide the light to such a point on the board that the examiner sees the reflection of the light exactly in the center of the pupil of the deviating eye. The position of the light on the board then indicates of course the number of degrees of the deviation. The relative positions of the patient and examiner are shown in Fig. 45.

This is one of the simplest and most convenient methods of measuring a lateral deviation.

FIG. 46.—The Worth-Black deviometer.

Another but less satisfactory method of using this tangent scale is to keep the light stationary at zero. The patient, as before, is one meter distant and he looks first at the light directly in front. The surgeon's eye should be in the same line, but a little lower. He then observes that the reflection is in the center of the pupil of the fixing eye

and how much it is decentered on the deviating eye. By guessing about how many degrees that decentering correponds to, the surgeon asks the patient to look at the corresponding number on the board, to right or left according to whether the deviation is an esotropia or exotropia. As the fixing eye turns, the one which deviates also turns, and finally, when the corneal reflection from the light at the zero point appears to the surgeon to be in the center of the pupil of the deviating eye, the number of degrees of that deviation will be the same as that which the normal eye has traversed.

(*G*) The Worth–Black modification of the flattened perimeter. Fig. 46. A standard supports an electric light, and from near the top of the upright there is a strip of glass extending horizontally, on which a tangent scale is marked. This scale is constructed with an arbitrary radius of sixty centimeters. By turning the standard the scale can be made to measure the deviation for either eye. The use of this is similar to that of the flattened perimeter when the lamp is placed at the zero point, but with this instrument the examiner looks from behind the tangent scale directly at the reflection on the eye. It is useful for children when the flattened perimeter might not be available.

(*H*) Priestley Smith's tape method (B 1328). The principle here involved is similar to that of the flattened perimeter when the light is at the zero point. For it we need a tape two meters in length, one half being colored black, the uncolored half being divided into twelve equal parts, or more exactly into a tangent scale to represent degrees.

To illustrate this method let us suppose that we have a case of esotropia of the right eye (Fig. 47). The patient, standing with his back to the lamp, looks straight ahead with the left eye, and holds near to that eye the end of the black part of the tape. The surgeon stands in front of the patient, holding in his right hand the ophthalmoscope, and also the center of the tape. At that point on the tape it is convenient to have a small ring (*o*) through which the handle of an ophthalmoscope can slip. In other words, the surgeon is one meter distant from the patient. If the

light from the mirror of the ophthalmoscope is then thrown on the patient's deviating (right) eye, the reflection of course will be seen near the outer edge of that cornea. The surgeon then takes the graduated portion of the tape near its center over his left hand. The free end is allowed to fall, and a light weight (*w*) is often attached to that end of the tape to keep it in place. He then directs the patient to observe the motion of his (the surgeon's) left hand, as he moves it slowly in a horizontal direction towards the patient's right. As both eyes turn toward the right, a point is reached at which the surgeon sees the corneal reflection in the center of the pupil of the right eye. As the number of degrees which the patient's left eye has turned toward his right side in following the motion of the hand is usually the same as the excursion of the right eye, we have, consequently, the amount which the right eye did originally deviate inward.

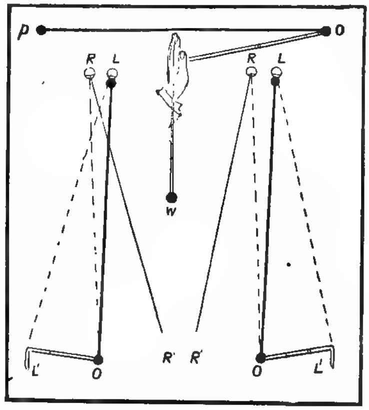

Fig. 47.—Priestley Smith's tape method.

This is a convenient and simple method for measuring deviations. With it, as with the flattened perimeter, we should remember, however, that when any paralysis exists the secondary deviation is not equal to the primary, but is greater.

(*I*) The tropometer can also be used for measuring all deviations, and for those which are inward, in an excessive degree, it is the only instrument on which we can rely. For it is evident that when a deviation inward is so great that the visual axis of that eye would pass through the bridge of the nose, all of the methods of measurement thus far described are useless. In employing the tropometer for this purpose, the patient is directed to look with the fixing eye at an object directly in front, and the measurement of the

deviation is made in the manner already described (Vol. I, p. 195). When using the Stevens tropometer, if the left eye of the patient happens to be the one which deviates, it is necessary for him, when looking with the right, to fix an object which is a little above or below the horizontal plane, because the tube is directly in front. When using the other tropometer, however, the patient can look straight in front with the eye which fixes the object, but it is necessary for the examiner to make sure that his own head does not intercept the distant vision of the patient.

II. Subjective methods of measuring the deviation. These are applicable to rather a smaller group of cases than are the objective methods, because often in heterotropia the deviating eye cannot recognize the second image unless gradually taught to do so. In cases of paralysis, however, the recognition of the second image is usually easy—often so easy as to be annoying to the patient.

(*A*) The production of diplopia is readily understood. If the right eye turns inward, as in Fig. 48, then as the

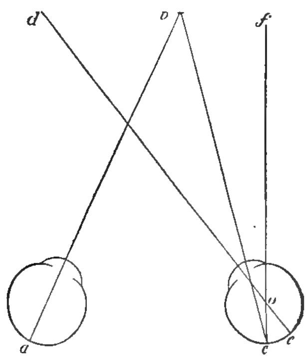

FIG. 48.—Homonymous diplopia, with esotropia in the right eye.

image fails on the inner surface of the retina (at *c*) it is projected outward and to the right in the direction of *f*, and we have as a result a homonymous diplopia. Or if, as in Fig. 49, the right eye turns outward, then the image of the distant object falls on the outer part of the retina and the image is projected to *f*. In that case, of course, we have a crossed

diplopia. These double images are so important that we should agree as to the significance of certain phenomena which they present.

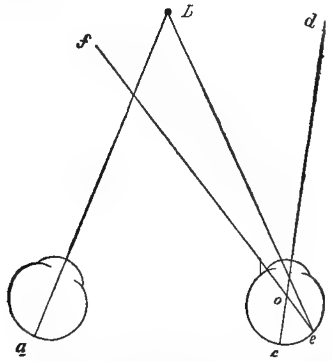

FIG. 49.—Crossed diplopia, with exotropia in the right eye.

Of the two images seen by the patient, the one which belongs to the unaffected eye we call the true, and the other the false. But if the vision of each eye is normal, then one of these images is just as real and clear as the other. It is easy enough to ascertain which one belongs to which eye by closing each eye alternately, but it is by no means easy, when the eyes are open, for the patient to decide where the object really is and where it only appears to be. Then both images seem equally real. If, however, the object is moved, it will be found that in one direction the distance between the images tends to grow less, while in another the opposite effect is produced, and their behavior thus with relation to each other assists the patient in distinguishing the true image from the false.

Von Graefe suggested that the most prompt and ready method of enabling the patient to arrive at a conclusion was to have him touch the test object. But this holds good only for a time, as the patient soon learns to correct his errors of judgment. The most reliable method, therefore, of ascertaining to which eye an image belongs, is to place a colored glass before one eye, and if it is before the one which has the better vision, the perceptive power of

the two is made more nearly equal. Sometimes the true image appears nearer to the patient than does the false. This is usually due to the difference of outline and general distinctness.

(*B*) The degree of the diplopia and therefore the amount of the deviation is ascertained in two ways—by measuring the distance between the double images, and by the strength of the prism which can be overcome.

(*a*) When measuring the distance between the images it is desirable to seat the patient in front of a wall, or plane surface, in the center of which the test object (a candle or point of light) is situated. The distance between the patient and the test object must always remain the same, and it is better to eliminate efforts at convergence. A rough estimate of the character and degree of diplopia can be made

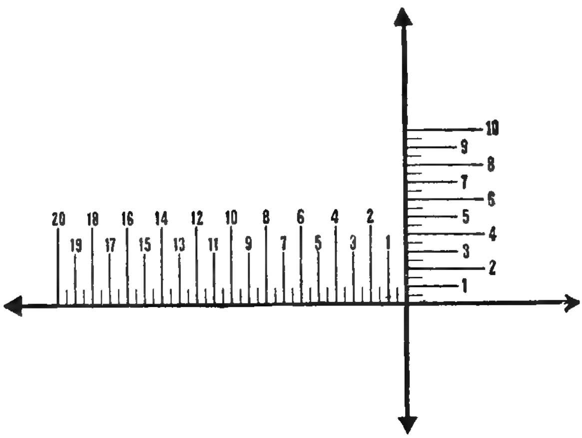

FIG. 50.—Ziegler's scale for measuring deviations.

without any apparatus whatever. Thus we may indicate the position of the false image with relation to the real one by keeping the latter in the center of the field of fixation, and the position of the false image can then be described with regard to the real one—for example, so many centimeters from the real image to the right, left, up, or down. Instead of measuring the distance each time between the images, it is convenient to place on the wall opposite the

patient a meter measure, or similar scale, on which the distances can be read off at a glance. Ziegler (B 722) placed a second such measure at right angles to the first, so that we can read off the vertical as well as the horizontal deviation. Fig. 50.

Inasmuch, however, as such linear measurements are arbitrary and do not bear any relation to degrees of an arc, Duane placed the light in the center of a series of concentric circles. Each circle is drawn at such a distance from the next as to mark off, in any direction from the center, a tangent scale of a circle whose radius is one meter. Fig. 51.

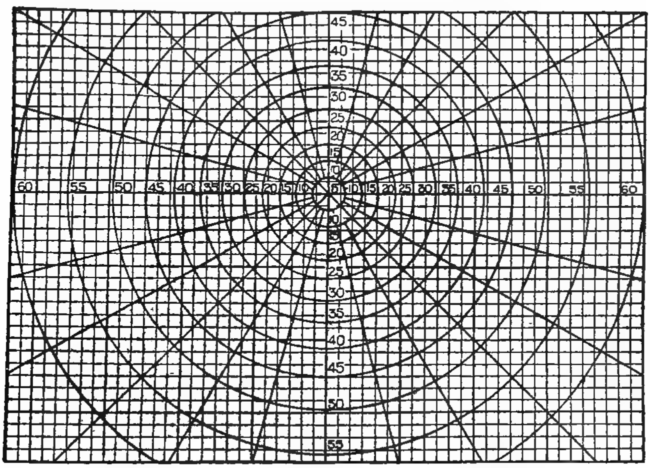

Chart used for plotting double images in paralysis, etc., and the field of fixation. The chart, which is 5¼x3¾ inches, is a precise facsimile of the reverse side of the curtain of the tangent plane, reduced to 1/20 of its natural size; the small squares of the checkerboard denoting two-inch intervals, the larger squares intervals of one foot. The circles represent intervals of 5°, and are drawn on the assumption that the patient is just 30 inches from the tangent plane. Under these conditions the checkerboard on the chart will correspond square for square to the checkerboard on the curtain, and a plot made on the latter by pins thrust into it to show the exact site of double images, the outlines of the field of single vision, the limits of the field of fixation, etc., can be transferred at once to the checkerboard on the chart.

FIG. 51.—Chart for plotting diplopia (Duane).

(*b*) The distance between the double images can also be expressed conveniently by the strength of a prism necessary to overcome the diplopia. It should be remembered, how-

ever, that when prisms are thus used, another factor usually enters into the question more directly, namely, the tendency to fuse the images. As this varies in different individuals, according to the distinctness of the retinal images, etc., when keeping records or making reports of cases we should specify in which way the diplopia has been measured.

(*c*) The movements which the images undergo with relation to any movement of the head is also of importance. We know that the instinctive desire of the patient is to turn the head toward the affected muscle; the farther away the object is from the side of the affected muscle, the nearer together do the images appear, and the reverse.

(*C*) Other subjective methods for measuring heterotropia are for the most part the same as those for the measurement of heterophoria. Several have been already described in detail (Vol. I, p. 224). It is unnecessary also to dwell upon their comparative value. Each surgeon soon decides upon the plan which he prefers, and each is apt to hold tenaciously to the opinion that his method is the best. Moreover, he often thinks so because he has become expert in its use. The reasons for selecting one of these tests or sets of tests in preference to another have been already given (Vol. I, p. 237). Among other methods we may notice:

(*D*) The method of measuring subjectively with the flattened perimeter. This is simple, after having learned how that measurement is made objectively. For this purpose we use the same board on which the tangent scale is marked, and the patient is placed in the same position with relation to it. The light is then moved along the board until he sees it directly in the line of vision of the deviating eye. The number of degrees between the zero point and the point which the light then occupies is, of course, the amount of deviation.

§ 4. **Which Method is Best?**—In general some one of the objective variety, as with all of these we eliminate the personal equation of the patient. For children and ignorant patients the strabometer with the arc, which has been described, is perhaps the most convenient, as no special position of the patient is demanded. For more intelligent patients,

the objective measurement with the flattened perimeter is preferable. Where special accuracy is required, especially with high degrees of esotropia where the corneal reflexes cannot be seen because of the projection of the nose, a tropometer of some form is not only a convenience but a necessity.

When operation is contemplated, reliance should not be placed on any one method, but the findings with one should be checked off by those of another. Careful measurements also should be made not only with the accommodation at rest, but with that function in different degrees of activity.

§ 5. **Photographs** of cases of heterotropia. These are often seen in chapters on this subject and in popular articles. But it should be remembered that they are not always reliable, as much depends upon the position of the patient and on the condition of the accommodation at the moment when the photograph is taken. Sometimes an esotropia may be of a high degree, but decreases gradually or entirely disappears if a full dose of a cycloplegic is applied to each eye.

In spite of these disadvantages, if photographs are conscientiously made, they give a very fair idea of the condition and are particularly useful for comparison before and after treatment. Probably the best way of making them is to focus particularly the corneal reflection. This method has been elaborated with considerable care by Maddox, and he figures a camera adapted especially for this purpose (B 263,p. 333). I have found, however, that these corneal reflexes can be brought out very satisfactorily simply by placing in front of the ordinary camera a mirror with a hole in its center. It is not even necessary to have a hole in the glass itself, but it suffices to scrape off the quicksilver from the back of the mirror over a space less than the size of the front lens of the camera. The mirror can be held in place with the clamp of a retort stand or in any similar simple manner.

III. Measurements of the position and character of the arc of rotation. The measurements thus far described relate to the *amount* which one eye deviates from the position which it should occupy—that is, the static condition. But for certain purposes it is desirable to measure the position and

the character of the arc of rotation and also the lifting power of the adductors—that is, the dynamic condition.

(*A*) Position of the arc of rotation. We have already considered various methods of measuring the field of fixation (Vol. I, p. 189), and as a normal eye sees every object toward which the visual axis is directed, therefore under such conditions the field of fixation corresponds to the arc of rotation. But when an amblyopia exists, as is frequently the case with heterotropia, then the field of fixation is often much less than the arc of rotation. Therefore for these abnormal movements it is more definite to speak of the "arc of rotation."

In regard to these apparently we should distinguish the normal, the relatively normal, and the abnormal arcs of rotation.

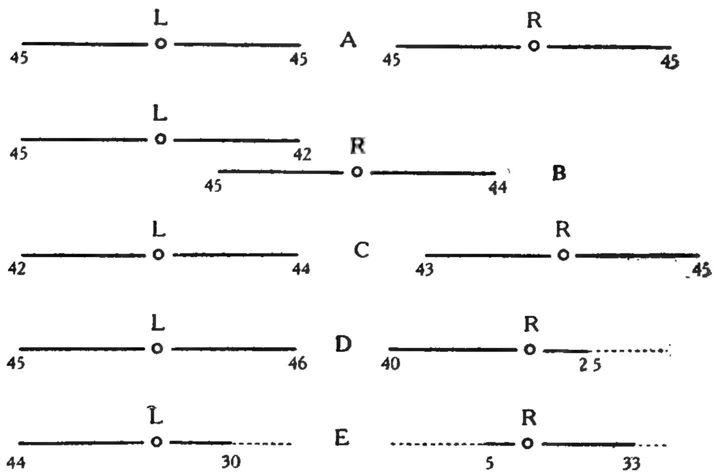

FIG. 52.—Diagrammatic representation of arcs of rotation.
(A) Normal.
(B) Esotropia of right, arcs of normal length but abnormal position.
(C) Exotropia of right, arcs of normal length but abnormal position.
(D) and (E) Arcs of rotation of right, abnormally short as in paresis.

(*a*) A normal arc is one of normal length measured from the primary position of the visual axes. It will be remembered (Vol. I, p. 196) that the eye can usually rotate laterally through an entire arc of at least 85 or 90 degrees and vertically through an arc of at least 80 or 85 degrees. It is true

that different students of the subject have obtained slightly different figures as the limits of the field of fixation, but these differences are rather of academic interest. For our present purpose, it is sufficient to suppose that an eye can normally rotate from the primary position in and out about 45° *or more.* As the motion in the horizontal plane is the one with which we have to do most frequently, we can represent that by diagram as in Fig. 52–A. In reality these two fields of fixation overlap each other, but it is most convenient to represent them in this way.

(*b*) A relatively normal arc is one of normal length, as measured from the position which the axis of the deviating eye occupies when the axis of the fellow eye is in the primary position. In measuring this, the position of habitual deviation should be counted as the zero point. Thus, suppose we have a case of esotropia of the left eye which measures ten degrees when the fixing eye is in the primary position. If we wish to measure the relative arc of rotation of the left eye, the head should be turned a corresponding number of degrees to the left. In order to do this, I have had the iron stirrup which holds the wooden bit of my perimeter adjusted on a vertical pivot, and an index passing over a horizontal arc shows how many degrees the face is turned to the right or left. If the eye can rotate *from that point* inward, and also outward 45 degrees, the length of the arc of rotation is normal, *in relation to* the position occupied by the visual axis when deviated in.

Although the arcs of rotation in normal eyes really overlap internally, we represent them most conveniently as in A. But in esotropia if the arc internally is normal, it must overlap the one for the other eye to an abnormal degree, and it is easiest to represent this as in Fig. 52–B. Strictly speaking, the adjacent portions of these two horizontal lines L and R should be superimposed, but, unless we use inks of different colors, this gives rise to confusion in our case records, or in printing, so that for practical purposes the arrangement here given proves the best.

Again, we can represent an exotropia with a relatively normal arc of rotation, just as we do the normal condition,

only with a considerable space between the arcs. Fig. 52–C.

(*c*) Abnormal arcs of rotation may be contracted in one eye in one direction or in all directions, or such limitations may exist in both eyes. Or the arc of rotation may be enlarged in one eye in one direction or in the corresponding direction in both eyes. Fig. 52–D and E.

(*B*) Character of the arc of rotation. If a person with normal eyes tries to look rapidly to the extreme right and left, as the globe swings from the limit of fixation on one side to the limit on the other, it does so in one steady, uninterrupted sweep which is quite characteristic. There it halts, then it swings back in the same way, and halts nearly the same length of time before starting again.

These movements of the globe have been photographed not only when the eyes are normal (Vol. I, p. 202), but when one of them deviates from the position which it should occupy. The number of the latter thus far made is comparatively small, but nevertheless sufficient from which to draw one or two conclusions. These are:

(*a*) In certain cases of deviation inward, the *character* of the swing of the globe from side to side is normal, or nearly normal. A photogram of the swing from side to side of a normal eye has been already given (Vol. I, p. 206). Very similar to this are the photograms which have been made of the deviating eye of a few children with esotropia—especially those in whom there were practically no symptoms of a paresis. But it should be understood that the photograms of cases of esotropia and exotropia are not always like those for the normal eye. Not infrequently there are considerable irregularities in the motions of the globe, as shown by the tracing on the photographic film, even when they cannot be recognized otherwise.

Thus in Fig. 53 we have a photogram of the motion of an eye of a young girl with esotropia. In this, A represents the extreme limit of rotation outward. From that point to B, the eye is entirely at rest. At B it commences to swing inward, and it should be observed that the oblique line between B and C is short and regular. Having reached the

extreme limit of rotation inward at C the eye is again practically at rest until near the point D. There it begins to rotate outward. At D a halt is made and the extreme limit of rotation outward is not reached until the point E.

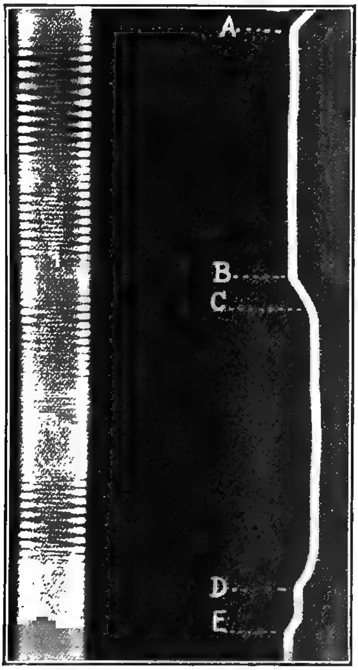

FIG. 53.—Photogram of the rotation in a case of non-paralytic esotropia.

The vibrations of the tuning-fork in this case are not well focused, and they are also irregular, as the film in the camera was turned by hand. But they are reproduced without any retouching of the negative. Not a little of the detail of such photograms is lost in making a half tone, and still more in printing.

The important point is that in the cases of esotropia in young persons in which a photogram has been obtained, the results are sometimes quite like those obtained from normal eyes, except, as will be mentioned under (*b*), that the period of rest at the outer limit seems to be abnormally

short as compared with the period of rest at the inner portion of the arc of rotation. Later we shall find that when a paralytic condition of any of the muscles is present, the swing in one direction or the other, or in both directions, is much more irregular.

(*b*) When an eye which habitually deviates moves rapidly from side to side, the *time* of the halt in the direction of the deviation is often greater than the halt in the opposite direction. Even when a normal globe moves in that way, and the fellow eye is closed, the halt inward is for some persons longer than the halt outward. Consequently it cannot be asserted positively that any peculiarity in this respect is characteristic of a non-paralytic deviation.

IV. Measurement of the lifting power. The method of doing this for normal eyes has been already described (Vol. I, p. 200). It has been observed that the lifting power of the adductors varies even under normal conditions, or at least such seems to be the case with the appliances thus far at our command. It would therefore be unwise to draw very positive conclusions as to measurements of the lifting power of deviating eyes. Moreover, it should be repeated that the lifting power is not to be measured only by the number of grams lifted, but also by the behavior of the eye while making the effort. Therefore in deciding what is normal or abnormal both of these elements should be taken into account.

In most cases of esotropia in which the lifting power was measured, it was found to be distinctly greater than normal, and the arc of rotation outward less than normal. This is what we would expect. It indicates an excessive action of the adductors with imperfect action of the abductors, and as a natural result the eye turns inward.

In regard to these measurements of the lifting power of the adductors, and also the character of the motion in and out as shown by photography, it should be repeated that the data thus far obtained are not sufficient on which to base positive conclusions. Moreover, as such measurements are inconvenient for the patient, and require no small amount of time and care on the part of the surgeon or his assistant, they are out of the question practically for most cases.

When, however, it is impossible to determine from other data whether a given deviation depends upon an excessive contraction of one group of muscles or a relaxation of the opposing group, and when this question ought to be decided before we decide in that case whether to make a tenotomy or the more difficult and tedious advancement, then for purposes of exactness it is eminently desirable to obtain if possible the additional information which the lifting power and the photographic measurements do afford.

CHAPTER II.

DIVISION II.

SYMPTOMS OF NON-PARALYTIC OR ACTIVE DEVIATIONS.

The foregoing methods of measuring deviations apply to those which we call non-paralytic and also to the paralytic. The methods of distinguishing these from each other will be considered later. It is desirable, however, to keep clearly in mind the class of cases with which we are now dealing.

A non-paralytic deviation is one in which there is no evidence of a subnormal (that is, of a paretic or insufficient or passive) action of the muscle or group of muscles, away from which the visual axis deviates. In other words, in the typical cases the deviation is due more to excessive action of one muscle or group of muscles than to insufficient action of the opponents. We might therefore with propriety call all of these the active, and those which are evidently of a paralytic nature, the passive deviations. But as the separation of these two types of deviation is not always easy, it is better to use also the more familiar terms, non-paralytic and paralytic.

Let us glance at the varieties and character of the deviation, and also at other symptoms which usually combine with it in varying degrees to form the clinical picture which we call a non-paralytic deviation.

I. Objectively we have:

1. The deviation itself. We should remember

(*A*) The degree varies greatly. It may be so slight as not to be ordinarily apparent,—such as exists, for example, with a large angle alpha (Vol. I, p. 35),—or the deviation may be noticeable as a decided deformity. In extreme instances

the edge of the cornea may even disappear behind the canthus, or the eye be turned entirely under one lid or the other.

(B) It may be primary or secondary. When one eye fixes a distant object and the other eye deviates from the position which it should occupy, that is the *primary* deviation. But when the eye which habitually deviates, fixes the same distant object, and the eye which habitually fixes, deviates from the position which it should occupy, that is the *secondary* deviation.

(C) It may be permanent or variable. The deviation may disappear from the eye usually affected, and show itself in the other. This is the *alternating* or *concomitant* form.

(*D*) Or we may find that for a day or two, or for months at a time, there is a deviation, and then for a time the axes may be in a perfectly normal position. This is the *periodic* form. In most of these cases there is an esophoria recognizable by the usual tests. But under certain circumstances, which occur naturally or which can be produced artificially, this esophoria passes into true esotropia.

2. The arc of rotation in the direction of the deviation is either normal or greater than normal.

3. The secondary deviation is equal to the primary. Reference will be made to this again in connection with the symptoms of paralytic deviations, in which case the secondary deviation is greater than the primary.

4. The position of the head is not altered.

5. In cases of non-paralytic esotropia when it has been possible to measure satisfactorily the lifting power of the internal rectus, that has been found greater than normal.

6. Photograms of the rapidity of the lateral motions are, as just stated, similar to those of normal eyes, except that when esotropia exists the halt inward is perhaps longer than normal.

II. Subjectively:

In non-paralytic deviations diplopia is usually absent except in the early stages or as elicited by suitable tests.

CHAPTER II.

DIVISION III.

ARRANGEMENT OF DATA AND PLAN OF STUDY.

§ 1. **Arrangement of the Data.**—Most writers on "Strabismus" or *Motilitätsstörungen* have taken the deviation as the fundamental fact. Thus we usually have chapters on Convergent Strabismus, on Divergent Strabismus, etc. Moreover, writers have too often approached the subject apparently with a conviction that most or all deviations are produced by one or two causes or groups of causes.

Therefore after enumerating the causes which might produce such a deviation, many authors describe the different forms of treatment without reference to the pathological condition which has produced the deviation in a given case. Or too frequently there is an evident desire to prove that most deviations are caused by the one pathological condition which seems particularly important to that writer. In this way we have running through the literature several so-called theories of strabismus, each theory having a certain number of facts for its support.

I must also plead guilty to this method of dealing with the subject. Long ago, in a work with other writers, I described convergent, divergent strabismus, etc., different causes being mentioned, but all forms of treatment considered together in one confused mass. That was also the plan outlined in the earlier years of the present study. But a more careful examination of facts long known, and of data more recently added, seems to warrant us in dealing with this phase of our subject in an entirely different way. We should recognize the very evident fact that the *deviation is not the disease*, but simply the most obvious symptom of one or

more different pathological conditions, each of which we can call in a general way a "lesion." Let us first consider each one of these lesions entirely by itself and ask:

First. WHERE is the lesion? Is it in or about the eye? If so, we have then some form of what we may call *Ocular Deviations*. Or the lesion may not be in the eye or near it, but instead, in the brain or nerves. Those deviations form another large class which we may call *Central Deviations*. This distinction has already been referred to.

Second. WHAT is the lesion? Is it some fault in the muscles themselves, or in the globe? If it is of a central character, is it some change in the nucleus or in the nerves themselves?

Third. In WHAT DIRECTION does this lesion cause the visual axis to turn? Does it produce an esotropia or exotropia, or what other form of heterotropia?

§ 2. **Plan of Study.**—It will be remembered that when dealing with muscle imbalance our first effort was to find what ultimate force or element or pair of elements varied from the normal type. Any such abnormal condition of accommodation, of convergence, or of torsion, when existing by itself, we called a form of simple imbalance. Then when two or more forms of simple imbalance occurred in the same individual, that combination constituted what we called compound imbalance.

In a similar way, in dealing with actual non-paralytic deviations it will clarify our ideas if we study first, as just stated, each one of the lesions which produces an actual deviation. Also, we may call these deviations which result from a single lesion, forms of *simple deviation*. The ocular lesions may be divided into the following groups:

(*A*) Muscular. The lesion may consist in an hypertrophy or atrophy, in a shortening or lengthening, or some abnormality in the insertion of a muscle.

(*B*) Ametropic. It may be primarily a hypermetropia, or myopia, or either of these with astigmatism.

(*C*) Retinal. It may be a congenital or acquired fault of the retina, or it may be

(*D*) Obstructive. There may be opacities in the refracting media, or it may be due to

(*E*) Other ocular lesions or abnormal conditions caused by individual or hereditary tendencies. Although some of these last are not lesions in any way, still they act through the eye itself as a primary cause of the deviation.

We shall try to define each of these to ourselves as clearly as the facts will permit; we shall glance at its frequency in order to obtain some idea of its relative importance, see what the symptoms are which characterize its pathology, and finally what forms of treatment are especially adapted to that particular lesion.

After having done this it is only necessary to glance at those more common cases in which two or more of the lesions combine in the same individual to produce a deviation of a non-paralytic nature, these being forms of *compound deviations.*

CHAPTER III.

SINGLE LESIONS WHICH PRODUCE ACTUAL NON-PARALYTIC DEVIATIONS.

(SIMPLE HETEROTROPIA.)

DIVISION I.

DEVIATIONS DUE TO ABNORMAL MUSCLES.

§ 1. **Definition.**—By the term muscular deviations or muscular heterotropia we will understand abnormal conditions of the extraocular muscles which produce deviations of the globe. Every deviation is, of course, due immediately to the action of one or more of the extraocular muscles. But we shall see that in the large majority of cases the original cause of the deviation is not an excessive or insufficient action of the muscles. Usually the original lesion consists in some imperfection in the globe itself, and then, because of the instinctive effort of the eyes to obtain the best vision, the muscles cause one eye to deviate. After that there results often an hypertrophy of one muscle or group of muscles with a corresponding relaxation or atrophy of the opponents. These more common cases will be considered in the chapter on compound heterotropia. At present we are to enquire whether abnormal changes originally in the muscles themselves, and in them alone, do produce any deviation.

§ 2. **Frequency.**—Although typical examples of this lesion are probably quite rare, still apparently they do occur. We shall see, when we study deviations which are the result of two or more lesions, that hypertrophy or atrophy of the recti do quite often result from other lesions.

For that reason it is desirable to consider the simple type briefly first.

§ 3. **Symptoms.**—It must be admitted that these are neither numerous nor reliable. Usually we can only arrive by exclusion at a diagnosis of some hypertrophy or shortening of one group of muscles, or atrophy or lengthening of the opposing group.

Among a considerable number of heterotropic patients, we do, however, occasionally find one who has little or no ametropia, vision seems practically normal even by the most exacting tests, and yet one eye deviates—usually in. How can that be explained? It has been customary to assume for these cases "a defect of the fusion faculty." But to assume this or anything else is simply to beg the question.

On the other hand, there are certain facts which indicate that these deviations are caused by anatomical variations from the normal type. Thus we know:

(*A*) Individual variations do occur in the length and size of the recti muscles themselves, and also in the form and the position of their attachment to the sclera. It was partly to call attention to these variations that so much space was given in the first volume to the anatomy of these muscles and their insertions.

(*B*) Examinations made of the two lateral muscles in cases of deviations with ametropia show that the stronger muscle is on the side toward which the eye deviates. Evidently, when another abnormal condition—the ametropia—is thus taken into account, we are no longer dealing with deviations due to a single lesion. But such anatomical evidence is admissible—if only corroborative—because it is quite as probable that the condition of the muscle is the primary cause of the deviation, and the ametropia a coincidence, as the reverse.

Evidence bearing on this point has been furnished by Schneller (B 1308) in a series of observations whose importance has apparently been overlooked. When making operations for tenotomy on one side, with advancement on the other, he availed himself of the opportunity thus

offered of laying bare the external and internal rectus for a sufficient distance from their insertions to permit measurements of each muscle, for example, from *b* to *c* Fig. 54.

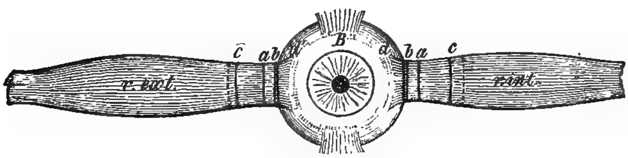

FIG 54.—View of the lateral muscles (Schneller).

In this way he was able to determine accurately the insertion, the width of the tendon, and the size of the muscle when divided.

First, in the cases of convergence with hypermetropia, the width of the tendon of the internal rectus was broader than that of the external, the proportion being as 100 to 74.2, or even a greater disparity between them. Moreover, the higher the degree of deviation inward, the larger, on the average, was the tendon of the internal rectus as compared with the external.

Second, in all the cases of divergence the tendon of the external rectus was broader than that of the internal, the proportion being as 107 or even 133 to 100. Several other points were apparently shown by these measurements, but it would require too long a digression to consider them here. Although the advisability of the surgical procedure may now seem doubtful, there is no question as to the importance of the data obtained.

In a case reported by Weiss (B 1337) post-mortem examination showed that the deviation was also toward the larger muscle.

In certain cases at least, the structure of the lengthened and weaker muscle undergoes a degeneration, as has been found by Mueller (B 1335).

Other testimony might be cited which tends to show that the muscle towards which the eye deviates is, in many cases, larger and better developed than its opponent. In a word, the facts which we have concerning

deviations due to abnormal muscles are few, and derived only from a few sources. But it is certain that such abnormal conditions of the muscles do occur, and the evidence is that these are as often a cause as they are a result of the deviation.

(*C*) In this connection it should be observed that blindness of one eye is usually followed by a deviation. If all the muscles were equally balanced no such deviation would result.

(*D*) A still smaller group of this class of cases is also worthy of notice. They are those in which again we find little or nothing abnormal in any part of the eye, and yet these patients have not only a deviation but of the concomitant form. A quantity of literature can be found on what is usually called concomitant strabismus. A few titles relating to it have been included in the bibliography and a considerable number of others have necessarily been omitted. The subject affords unusual opportunities for theorizing, but, after all has been said, one is inclined to come back to the opinion of von Graefe (B 1301), that these cases are due usually to a lengthening of both externi or of both interni.

Evidently what we need for this part of our subject are post-mortem examinations of the ocular muscles, in cases in which the more usual lesions in the eye or in the brain are apparently absent. The condition found by one such examination, carefully conducted, is of more value than innumerable theories.

§ 4. **Treatment.**—Naturally in the treatment of these cases the important point is to determine as nearly as we can whether the deviation is of an active or of a passive type. Then, if good vision is present, muscle exercise can be practiced to advantage. When, for any reason, such exercise is not practicable, operation is the only treatment available. The details of this will be given in the last part of these studies.

CHAPTER III.

DIVISION II.

DEVIATIONS DUE TO AMETROPIA.

SUBDIVISION I.

Hypermetropic Esotropia.

§ 1. **Definition.**—Hypermetropic esotropia results from hypermetropia with or without astigmatism. This is one type of what has long been described as "strabismus," or "squint." Galezowski and others call it "optical," or "functional" strabismus.

In one of the earlier volumes of Graefe's *Archives* Donders (B 1303) called attention to the intimate relation between the deviations of the visual axes and ametropia. The studies on this point made by himself and by others subsequently have proved beyond question that ametropia is a cause of deviations inward. It is probable that our knowledge of this whole subject would be much farther advanced if, long ago, we had separated this group of cases clearly from all others. For, as we shall see, the pathological conditions are for the most part well defined, and the treatment is much better understood than in other forms of heterotropia. In considering this class of cases by themselves many points must be referred to which pertain equally to esotropia due to other causes or even to exotropia. This understanding will save repetition later.

§ 2. **Frequency.**—Hypermetropic esotropia, either in its

pure type or combined with other forms, is by far the most frequent variety of esotropia with which we have to deal.

Schweigger found hypermetropia in 66 per cent. of all cases of convergent strabismus, Mueller in 76 per cent., Donders in 77 per cent., Stillwag in 78 per cent., and Isler in 88 per cent. These different results are due to the confusion as to what should be included under that elastic term "convergent strabismus." It is due also to the number of individuals from whom the conclusions were drawn, and especially to the manner in which the examinations were made—whether with atropin or not. For that reason we should place in quite a different list such measurements as are given by Priestley Smith (B 1414). He examined 310 cases of abnormal convergence under atropin with the following results:

Myopia	1 %
Emmetropia and hypermetropia to 1.5 D.	11 %
Hypermetropia from 2 D. to 3.5 D.	34 %
Hypermetropia from 3.5 D. to 4 D.	39 %
Hypermetropia from 4 D. and above	15 %

Careful examinations of this kind show therefore that, taking cases of abnormal convergence as they come, decided hypermetropia is present in 88 per cent.—or counting those under 1.5 D., in considerably over 90 per cent.

§ 3. **Symptoms.**

(*A*) The esotropia is said to occur more frequently with the moderate than with the low or high degrees of the hypermetropia, but this is not proven.

(*B*) The deviation develops in early life, usually in childhood.

(*C*) The degree of the deviation is usually moderate. In the early cases it is seldom more than twenty to thirty degrees, although later, if vision has become much impaired, it may considerably exceed that, or, in the advanced cases, one cornea may be almost hidden at the inner canthus.

(*D*) The degree of the deviation is often approximately in proportion to the effort of accommodation. Very many persons, with little or no hypermetropia, can make themselves squint by accommodating to a near point. In

the language of school life they "play looking cross-eyed."

(*E*) A full dose of a cycloplegic or suitable convex glasses usually cause the deviation to lessen; sometimes the visual axes become parallel almost at once.

(*F*) The esotropia is of an active rather than of a mixed type, especially in the early stages, and then:

(*a*) The extent of rotation inward is large.

(*b*) The extent of rotation out is normal or less than normal.

(*c*) The lifting power is large.

(*d*) The period of rest at the end of the swing inward is sometimes abnormally longer than at the outer limit.

§ 4. **Pathology.**—This may be stated in a word as an abnormal relation of accommodation to convergence. That is ordinarily known as Donders's Theory of Strabismus, although now the typical condition may be considered not a theory but a fact. Briefly stated, it is as follows: As accommodation and convergence always act together, the excessive accommodation which is necessary in hypermetropia requires also an excessive convergence. Hence, it was said, the strabismus.

If Donders and subsequent writers had limited this statement to a certain class of cases, and admitted also the existence in other cases of some other causative factor or factors beside the hypermetropia, that statement would probably still remain unquestioned. But if hypermetropia were the only cause of esotropia, then every hypermetrope ought to have the same deformity. The facts now at our command seem to indicate that hypermetropia alone is sometimes the only cause of a deviation. But when there exists a congenital preponderance of one set of muscles over the other, or some fault in the power of fusion or perception, or some other lesion, *plus* the hypermetropia, then the combined effect is to produce a deviation. These multiple lesions are simply mentioned now, and will be referred to later.

§ 5. **Course and Sequelæ.**—If the esotropia is allowed to remain uncorrected the deviating eye seldom continues in

the same position or condition. The changes which it undergoes are as follows:

1st. Spontaneous cure may result. It is no unusual thing to notice that a child squints at intervals when three or four years old, that this becomes less marked a few years later, and then disappears altogether. 2d. A deviation which was periodic becomes permanent. This is the usual course. 3d. The vision of the deviating eye decreases. As this is a function of the retina it will be dealt with in the chapter relating to deviations resulting from different causes.

§ 6. **Non-operative Treatment.**—As hypermetropia is always present in this group of cases, we need to consider the treatment only from the standpoint of the refraction. As far as the treatment of the hypermetropia is concerned, it resolves itself into dealing with (*A*) cycloplegics and (*B*) corrective glasses.

(*A*) As to cycloplegics:

(*a*) The first question is—Which drug shall be used? That makes but little difference. Atropin, to which we are all accustomed, is the most convenient and in general is the best. A little care should be exercised, however, to begin with a weak mixture, preferably one with vaseline, until we can be certain that there exists no idiosyncrasy in that individual. While the pupils remain dilated, a pair of colored glasses adds very much to the patient's comfort. At first, many objections are made to these by small children, but even the most fractious and nervous will soon become accustomed to their presence and will instinctively put them on in spite of the annoyance complained of at first. Moreover, it is convenient to have the colored glasses ground so as to correct the total hypermetropia.

(*b*) How long should a cycloplegic be continued? A few applications are quite insufficient. The accommodation should be relaxed almost constantly, not for weeks but often for months. If the relaxation is continued so long, is there no danger that it will be permanent? A considerable search for such instances revealed none which is well authenticated, but in view of the fact that impairment of the power of accommodation is even possible, it is good practice to omit the

cycloplegic occasionally, if only that measurements may be made of any improvement gained.

(*B*) Corrective glasses. These should be what the term indicates and be fitted as exactly as possible. This is by no means easy with children who read imperfectly or not at all. But it should be remembered that the object is not only to relax the accommodation, as does the atropin, but that the corrective glasses should give a clear retinal image, and in that way act as a safeguard against amblyopia from non-use.

The treatment with glasses is so rational and convenient that it ordinarily meets with no objection—at least not in the towns in America, and with the educated class. As these cases occur most frequently with children, the question naturally arises as to how early in life we may begin with the use of spectacles. Formerly it was considered unwise to provide children with glasses until they are old enough to read a few letters. But practitioners, especially in America and in England, are learning to avoid the danger of amblyopia from non-use, and to advise glasses for even young children.

Thus Worth says: "A squinter who has any notable refractive error should wear spectacles, no matter how young he may be. Many of my squinting patients have worn glasses before three months of age, and have been cured before they were old enough to walk." For safety and convenience he mounts the glasses for very young children in frames such as are shown in Fig. 55. Statistics show that after a time the eyes become practically "straight" in about thirty to thirty-six per cent. of all cases treated with glasses.

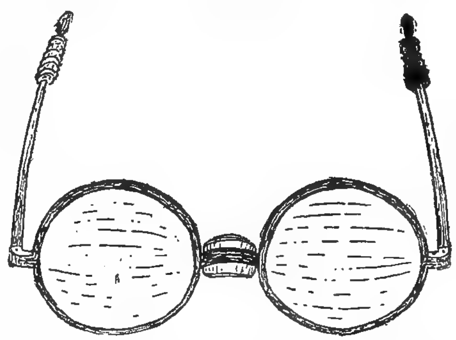

Fig. 55.—Safe frames for young children (Worth).

But as many such eyes also become "straight" without the assistance of glasses, it would be interesting to have a series of each class which have been accurately diagnosed and

then carefully studied. The results would help us in deciding whether glasses really are of great advantage to these young children, and if so, whether the beneficial effect is because of the influence on the accommodation, or on the perceptive apparatus, or on both.

CHAPTER III

DIVISION II

SUBDIVISION II

Myopic Exotropia.

§ 1. **Definition.**—This is an exotropia resulting from a myopia with or without astigmatism.

§ 2. **Frequency.**—Pure types of this condition are much more rare than those of hypermetropic esotropia. Usually there are secondary changes also in the retina, thus producing compound lesions, and such cases are not under discussion now. The best types are met with when the exotropia is beginning to be permanent, and before secondary changes in the retina or elsewhere have begun.

§ 3. **Symptoms:**

(*A*) The myopia is considerable or even in a high degree.

(*B*) The deviation seldom develops in youth—more frequently in middle or later life.

(*C*) Its degree usually increases as years advance.

(*D*) The degree of deviation is not affected by efforts of accommodation.

(*E*) Cycloplegics have no special effect upon the deviation.

(*F*) The extent of rotation outward is large.

§ 4. **Pathology.**—This is to a great extent a question of dynamics. The myopic eye is an ellipsoid, around which the external rectus passes in contact with the globe for an unusually long distance. Thus the muscle makes traction to better advantage than when the globe is of the normal form. Moreover, as the fibers of the superior and inferior oblique are then inserted farther posteriorly from the center of

motion, they also tend in a greater degree than usual to rotate the globe outward. Under such circumstances it is not surprising that a large proportion of the cases of divergence should occur in myopic persons.

The explanation given by E. Hansen Grut must also be taken into account. It will be remembered that he considers divergence as a normal condition of the eyes at rest, and the condition described by him may act as a secondary cause in some cases of myopic exotropia (B 507).

CHAPTER III.

DIVISION III.

DEVIATIONS DUE TO IMPERFECTIONS IN THE RETINA

§ 1. **Definition.**—In this group of cases the deviation is caused primarily by some imperfection of perception. As yet it is impossible to say whether what we call a "defect of the fusion faculty," or an "amblyopia," etc., is in the retina itself or in the brain. For our purposes, it will be sufficient to include in this group all cases in which the function of the retina is so impaired as to result in a deviation of the visual axes, even though anatomical changes are not visible.

§ 2. **Frequency**—It is not probable that we shall ever know how frequent such cases are, because subjective measurements are impossible in young children, in regard to whom such data are most desired. For this reason the tables giving such proportions are worthless. But measurements of the visual acuity, and of the binocular vision in subjects old enough to give reliable answers, show that cases in which some imperfection of the retina is apparently the only lesion present constitute one of the large groups with which we have to deal. But to assert in a general way that "the essential cause of squint is a defect of the fusion faculty" is to take for granted what no one can prove, especially for young children.

§ 3. **Symptoms**:

(*A*) The deviation develops in early life.

(*B*) It may be in any direction—usually in or out.

(*C*) Its degree is apt to be moderate.

(*D*) The amount of the deviation is not affected by efforts of accommodation.

(*E*) Cycloplegics do not affect it.

(*F*) Concomitance is usually absent.

(*G*) The extent of the rotation, the lifting power, and the rapidity of motion depend on whether an active type continues or a mixed type has developed—if so, in what direction and to what extent.

§ 4. **Pathology.**—When the lesion is apparent with the ophthalmoscope it is usually some familiar change in the retina only, or also in the optic nerve or choroid. These require no comment here. Often, however, the changes are not visible in this way, even if in the retina.

As we give various names to the conditions, real or imaginary, which relate to the pathology of the retinal deviations, we should define to ourselves one or two of those most frequently referred to. The failure of writers to explain what they mean by terms which are indefinite in themselves, has helped to confuse this whole subject. Therefore let us understand a little more exactly what we mean by:

(*a*) Imperfect desire for fusion. When studying convergence (Vol. I, p. 297) we have already seen that what we call the power of fusion "depends upon two factors—the actual strength of the recti muscles, and the so-called instinctive desire for fusion." This last is also called the "fusion faculty." Although we do not know whether it is a function of the retina or the brain, there are apparently individual variations within normal limits. A defect of this desire for fusion may exist even when the vision of each eye separately is good. But ordinarily some visible imperfection of the retina, or an amblyopia with corresponding imperfect vision, is present with any such lack of the desire for fusion.

It was found long ago that by certain methods of training, to be described presently, it was possible to improve the vision of an amblyopic eye, and as the desire for fusion gradually increased the deviation was gradually overcome or outgrown. It was also learned that if such training was not instituted in rather early life, and sufficiently to improve the vision, more or less blindness remained. Some ophthalmologists have therefore argued that an imperfect desire for fusion is the primary cause in every case of deviation; but

it has been shown already that so broad a generalization is not warranted.

(*b*) False macula. A considerable literature has grown up about the question whether or not such a condition as a false macula exists. That has never been demonstrated anatomically in the human subject, although we do know that among certain birds—for example, the swallow tribe—two foveæ can easily be seen on section. The term "false macula" therefore is used to describe not an anatomical but rather a functional condition. Thus when one visual axis has turned in for a long time, the function of a spot on the internal portion of the retina of that eye becomes practically the same as that of a macula. For the eye not only fixes with that macula, but when the image of an object falls externally to this spot, that image is projected inward. Or when the image falls to the inner side of the spot, the object is projected outward. The results of this condition are especially apparent when such a deviating eye has been brought by operation into the position which it should occupy.

Thus in a case of esotropia operated upon during the last year the visual axes were brought into an exactly normal condition, as shown by several tests. Nevertheless, the young man complained greatly of diplopia. Fortunately, when such a false macula has existed, the diplopia usually decreases gradually. The symptom is of importance, however, as indicating two things: the fact that perceptive power similar to that which exists in a macula can develop in another portion of the retina, thus causing the deviation, and also that when the position of the eye is changed and the image is made to fall on the anatomical macula it becomes after a while the physiological macula also.

(*c*) Amblyopia. This term, as we know, is another of our nosological waste-baskets. It includes those changes in the retina which cannot be seen with the ophthalmoscope, of whose nature we know nothing as yet, but whose existence we recognize. As the amount of amblyopia varies greatly, much confusion has been caused by using one term for all degrees, from slight imperfections of vision to practical blindness. Various suggestions have been made to obviate

this difficulty. We can indicate roughly the degrees of imperfect vision by the words "slight," "great," and "very great," or by numerals 1, 2, 3, as we do intraocular tension.

As it is always difficult to measure the vision of a child who does not know even a few letters, different rough tests for this purpose have been devised. The usual practice is to have the mother hold the usually fixing eye of the child closed, while various familiar objects of gradually decreasing size, such as a knife, pencil, penny, etc., are shown to the patient, and he is expected to name them. Very often, however, we wish to determine, at least approximately, the vision of such an eye, even before the child knows the names of such articles. Or he may know the names and yet give replies so indefinite as to make it doubtful whether the object has really been seen.

A very simple and excellent plan has been suggested by Worth (B 1316, p. 88) for these cases. After gaining the confidence of the child, the habitually fixing eye is closed with a bandage and an ivory ball of considerable size is rolled or placed on the floor for the patient to hunt for and pick up. Then a smaller ball is used, and if he sees that one at a certain distance, a still smaller one is used. With this simple game, it is possible with most children to obtain a very fair idea as to the amount of vision existing in a deviating eye.

For older children or for adults greater exactness in diagnosis is possible, and as that always means more intelligent treatment, it seemed desirable to arrange what may be called an amblyopia scale, for use in a stereoscope. It is constructed as follows:

On the card before one eye there is a horizontal heavy black band about five centimeters long by one centimeter wide, extending about half the length of the card. (Fig. 56.) On the adjacent side of the card, and on the same horizontal line, another band of the same size is drawn. This second one, however, is divided into about ten sections of equal size, each section being a shade darker than the preceding. When a person with normal eyes looks at this card through

the stereoscope, the band of solid black completely overlaps the graduated band. This solid band merges into the blackest of the ten sections and seems to be a part of it. But if the sections are properly shaded, and if the eyes of the observer are quite normal, he will be able to distinguish the solid band from the next lighter section (No. 2) of the graduated band. The section which is of the next higher shade still, he distinguishes without difficulty, and of course can count all the other shades to the end of the series. If, however, one eye is partly amblyopic, then the second, third, and even perhaps the fourth section seem also to be of solid black, while if the degree of amblyopia amounts almost to total blindness, even the lightest section merges into the solid black. By reversing the position of the card, the solid black band can be brought before either eye. Its convenience is apparent at a glance. When placed before the amblyopic patient, he is simply asked how many shades he can distinguish as "shining through" the black band, from the lightest toward the darkest part of it, and the number of sections which he can thus count measures, approximately at least, his power of perception. This method is so simple that with it a patient can test his own amblyopia from time to time, or a mother can determine the amount in her child, if old enough to give intelligent replies, when any treatment has been advised for the purpose of developing the imperfect vision.

Fig. 56.—Amblyopia scale of the author.

§ 5. **Treatment.**—This consists naturally in efforts to restore the function of the retina. If any inflammatory process has caused the imperfect vision, that must first, of course, be cured. But in the vast majority of cases it is a question of improving an amblyopia. One of the earliest plans proposed for this purpose was:

(*a*) Covering the better eye. If the perception in each

eye is fairly good, or if the vision of the deviating eye is practically gone, or if early life has passed, this method is of little or no use. The best results are obtained in children in whom we can determine that the vision of one eye is good, but the other just imperfect enough not to take any important part in the act of vision.

The length of time which it is worth while to persist thus in covering the imperfect eye depends upon various factors, most of all upon the gain in the central vision or in the field, as this can usually be determined in the older children by measurements made at intervals.

(*b*) Bar reading. If a pencil be held vertically in front of a printed page and one eye be closed while an attempt is made to read, certain parts of the paper are of course obscured by the pencil. If, however, both eyes are opened the person can read without difficulty, each eye, as it were, seeing around the pencil. This simple fact has been turned to account in teaching a partly amblyopic eye to do its part in the act of binocular vision. It is accomplished by having the patient hold a pencil or bar in front of the paper which he reads. For the popularizing of this plan we are indebted to Javal and to his former associate, Bull. Fig. 57. A simple modification of this plan has been suggested by Wells, which consists in attaching the bar to a head band, in such a way that the bar is always in the desired position.

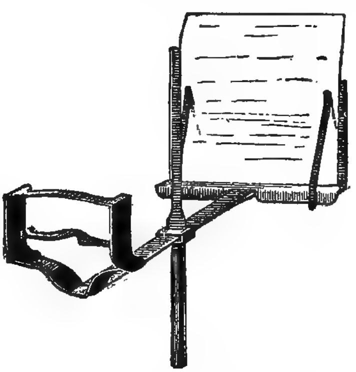

FIG. 57.—Book rest for bar reading (Javal).

A decided objection, however, to the head band is that when made tight enough to be held in place it is cumbersome, hot in summer, and not infrequently causes headache by pressure. Children will none of it. It has been found that these objections could be obviated largely by attaching the rod to a metal head-spring such as surgeons use

for electric illumination. Fig. 58. When the tension of the spring is adjusted as the patient wishes, it is worn with comfort and its pressure soon forgotten.

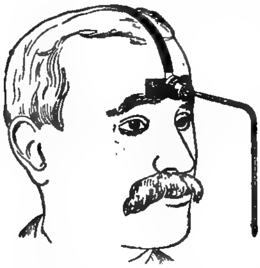

FIG. 58.—Arrangement of the author for bar reading.

(*c*) Exercises in stereoscopic vision. Thus far we have studied the stereoscope as an instrument for testing binocular vision, for testing and exercising the horizontal muscles, and for measuring the degree of amblyopia. We shall now consider it as a means of improving the vision of an amblyopic eye. Its virtue consists in the possibility of producing on each retina a separate image of the object looked at, even when one eye deviates. The merits of this method are shown by the general use of the instrument in its various modifications. While they all require the amblyopic eye to do a certain amount of work, in order to obtain stereoscopic vision at all, that amount is often small, and can be increased only with difficulty, as long as the perceptive power of the other eye remains much the better of the two. Therefore, it is desirable to lessen the distinctness of the image in the better eye. Ramsay attempted this by making the picture before each eye translucent and placing behind the test pictures an electric light whose intensity could be made to vary on one side or the other as desired. This has also been done in later modifications of the Worth–Black amblyoscope.

After a little experimenting the same result has been obtained simply by placing a colored glass before the better eye, thus lessening the distinctness of the corresponding image. In order to accomplish this, discs of different shades have been attached to a small wheel near its circumference, and these made to rotate in front of each eye, as the lenses of an ophthalmoscope are made to pass before the opening in the center of the mirror. The instrument is seen in Fig. 59. It has the great advantage that no special light is required, and that a patient can take the simple apparatus home and practice with it at his leisure.

The method of using it suggests itself at a glance. The

disc on the side of the more imperfect eye is rotated so as to leave the opening before it without any colored glass. If the amblyopia is very great, it is necessary to dim the vision of the better eye to a corresponding degree by turning the darkest glass before it. By thus equalizing the

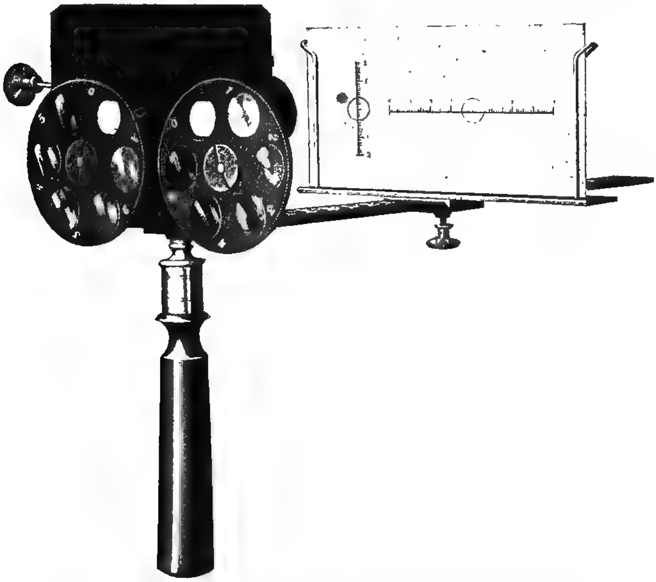

FIG. 59.—Stereoscope of the author for the treatment of amblyopia.

vision more nearly, the actually imperfect eye sees as well as its fellow. If, however, the degree of amblyopia is not very great at the beginning, or if, having been very marked, improvement has taken place, then a lighter glass is sufficient to equalize the distinctness of the two retinal images. Thus the density or number of the colored glass used is also a measure of the amblyopia present. The changes in the shades of the colored glass can be made irrespective of the picture on the card which is looked at. In the exercises designed to increase the perceptive power of the weaker eye, one kind of a picture is practically as good as another.

But if, as usual, we wish at the same time to exercise the muscles, we can use, with these same colored glasses before the

better eye, any one of the set of cards which have been already described, or the one which happens to be illustrated in the figure given. Of course this identical card is not essential to the treatment of the amblyopia; it is simply convenient when development of the muscle power also is desired.

The results with these different methods vary greatly. Each surgeon is apt to laud the plan to which he is most accustomed, while some discard them all as bothersome or worthless.

The requisites for good results with any of these methods are:

1st. A diagnosis as accurate as possible, not only as to the nature of the retinal imperfection but its degree.

2d. A determination on the part of the surgeon to exercise infinite pains and care in the treatment, especially if the patient is a child.

3d. Unusual intelligence of the patient or his parents in appreciating the object to be gained, and persistence in carrying out the details of the tiresome exercises day after day, for weeks or months if necessary.

Evidently these requisites are not at the command of the average patient, and they call for infinitely more intelligence and power of persistent effort than is possessed by the usual applicant at a dispensary or hospital. Moreover, to judge by the appearance only, training the retina by any method is slow and unsatisfactory compared with the brilliant results of operation.

But we all agree, probably, that no result is apt to be lasting, even with operation, unless some vision remains or can be obtained in the deviating eye. Moreover, the best and most lasting result is not obtained in any case until we have also the best vision possible in each eye. If, then, the patient were the surgeon's own child, would it seem worth while to struggle along day after day in this effort to improve the vision before operation, or after it, or perhaps to avoid operation entirely? The answer to that question is a safe guide for the routine of our daily work.

CHAPTER III.

DIVISION IV.

DEVIATIONS DUE TO IMPERFECTIONS IN THE REFRACTIVE MEDIA.

§ 1. **Definition.**—This group of cases includes those in which some opacity of the refractive media constitutes the primary cause of the deviation. If there were any question as to whether an opacity of the cornea, for example, can produce a deviation, the cases which are unfortunately common would answer it. These are the children born with apparently perfectly normal eyes. An ulceration of the cornea developed and a small superficial cicatrix was left. Immediately after, a deviation of one visual axis followed; then gradually, as the nebula absorbed, the deviation also lessened, and when the cornea was practically clear, the deviation had disappeared.

§ 2. **Frequency.**—We have as yet no very reliable data on this point. It is certain, however, that pure types of these cases are much less frequent than those referred to in the second or third divisions.

§ 3. **Symptoms.**

(*A*) The deviation develops at any age, following as it does the formation of the opacity.

(*B*) It may be in any direction—usually in or out.

(*C*) The degree of the deviation varies.

(*D*) It may or may not be affected by efforts of accommodation nor by cycloplegics.

(*E*) Concomitance is usually absent.

(*F*) The arc of rotation, the lifting power, the rapidity of motion, and the periods of rest depend on whether an active or passive type has developed—if so, in what direction and to what extent.

§ 4. **Pathology.**—Among these imperfections of the media, our attention should be directed especially to opacities of:

(*A*) The cornea. The one which most frequently produces a deviation is a small spot near the center.

(*B*) The lens. A deviation frequently follows a small capsular opacity near its center. It is quite often seen with pyramidal cataract and occasionally with lamellar cataract, but seldom following the ordinary nuclear senile cataract.

(*C*) Opacities in the aqueous humor, strictly speaking, are never sufficient to produce a deviation, but may do so when an iritis has left deposits in the pupil. Those in the vitreous are seldom of such a size or in such a position as to obscure any one part of the retina, and therefore their influence is even less than those which occur in the aqueous humor.

§ 5. **Treatment.**—Each lesion must be considered by itself and treated according to well-known surgical principles. Such a case is only partially treated, however, if we limit our efforts simply to the opacity itself. For, as long as it remains it produces an imperfect retinal image, and this in turn causes an amblyopia from non-use. Evidently therefore there exist, almost from the first, the same indications for treatment as in retinal or in muscular deviations.

CHAPTER III.

DIVISION V.

SOME SECONDARY CAUSES WHICH MAY CONTRIBUTE WITH ANY SINGLE LESION TO PRODUCE A DEVIATION.

It will be remembered that we are studying in this chapter only those comparatively rare but instructive cases in which the deviation is due apparently to a single lesion. We have thus far examined four lesions or kinds of lesions, any one of which, under certain circumstances, is capable of causing a deviation of a visual axis in some direction. Other lesions which also produce the same effect may be found by future students. In the next chapter we shall see that in most cases two or more of these four principal lesions usually combine in varying proportions to produce that most evident symptom—the deviation. Before turning our attention to such combinations of those four lesions, let us glance at a few minor causes, which may aggravate any single lesion in producing a deviation. Thus we know, of course, that an ametropia, imperfect perception, or opacities of the media are common without any deviation of a visual axis. But when any one of these exists, and there is added to that lesion some secondary cause—such, for example, as an occupation which taxes the accommodation—then the lesion with the secondary cause results in a deviation inward of one visual axis. Among these secondary causes we have :

1. **Occupation.**—Although it is not certain that persistent use of the eyes for any given purpose can produce a deviation, yet the fact that certain occupations are accompanied by nystagmus, and that prolonged efforts of accommodation can produce spasm of the accommodation, with other similar facts, render it probable that certain occupations may assist in producing deviations, especially those inward.

§ 2. **Imitation.**—The play which children have of "looking cross-eyed" is undoubtedly harmless to the vast majority with normal eyes, but if there exists a hypermetropia or an imperfect retinal perception it is probable that such a habit tends to produce the permanent deviation.

At least we have the testimony of intelligent mothers that the turning in of a child's eye became apparent or permanent after frequent indulgence in such a habit for the amusement of others, and examination shows some one of the usual lesions to exist, but in rather a slight degree.

§ 3. **Anisometropia** is occasionally associated with deviations, and in such a way that there are good reasons for concluding that this condition also may be a contributing cause.

§ 4. **Influence of Heredity.**—This subtle something which we call heredity is mentioned last because we know least about it, if indeed we can be said to know anything. But its effect is perhaps the most direct and important of any yet considered.

Instances of this kind are probably known to almost every practitioner. Worth (B 1316, p 59) thinks this influence is apparent in about half of our cases. Hospital records furnish numerous examples. It would lead us too far afield to go into details concerning this phase of the subject, but we find deviations of the visual axis in different members of the same family so often as to leave not a shadow of doubt as to the influence of heredity on this condition.

CHAPTER IV.

DIRECTION OF THE DEVIATION.

Thus far we have devoted our attention rather to the lesions which produce any deviation than to the direction assumed by the visual axis. Evidently this direction is determined ultimately by the strength of one muscle or groups of muscles, as compared with the opposing muscles. This fundamental fact has been too often obscured by theories in regard to the importance of this or that cause in the production of what is generally called "strabismus." Moreover, this relative strength of the muscles is alone sufficient to explain why the eye turns in a given direction under most circumstances. For, as the horizontal recti are the largest and strongest, it is natural that most deviations should occur in that plane, or obliquely rather than up or down. Besides, in that very large class of cases in which hypermetropia or imperfect retinal perception exists, or in that larger group, as we shall see later, in which these two lesions exist at the same time, it is also natural that in the effort to obtain the best vision, one visual axis turns in or out, still in the horizontal plane or near to that plane.

In those unusual cases of exotropia with hypermetropia and esotropia with myopia, if the perceptive power is normal, we can not explain them except by assuming an abnormal condition of the extraocular muscles.

Again, how can we account at all for those less marked but still well-defined cases in which one visual axis does turn almost directly up (hypertropia), or down (hypotropia), or in an oblique direction. Unfortunately, thus far no dissections have been made of the ocular muscles in such individuals,

and therefore it is impossible to say anything as to the condition of the vertical muscles. Thus in a given individual it is at least possible that the superior rectus, for example, was congenitally larger than normal or possessed in a great degree some such peculiarity as can be found in a slight degree in every dissecting room.

It is certain, however, that the tendency of one eye always is to deviate, if by doing so better vision can be obtained or a diplopia can be obviated. If therefore an obstruction in the media, however small, does occur, or if there is some imperfection in an upper or lower portion of the retina or certainly in the macula—if with either of these conditions, or under any similar conditions, better vision is obtained by a vertical deviation, evidently such a deviation will at once occur. The truth is, that while these vertical or oblique deviations are met with in every large hospital, very few accurate studies have been made of their etiology.

Several writers have described manifest deviations of both eyes upward (anotropia) or of both downward (katotropia). But such evidence as we have about these cases indicates that when they do exist they are of a paralytic nature, and simply varieties of conditions which will be described later.

CHAPTER V.

DEVIATIONS DUE TO TWO OR MORE LESIONS.

(COMPOUND HETEROTROPIA.)

After studying the simple forms of heterophoria, we saw how these united to produce various forms of compound heterophoria. In a similar manner we are now ready to consider those deviations of a non-paralytic character which are due to the combined effect of more than one lesion. This is of course by far the largest group. As we have already found at least four different lesions which can produce a deviation, evidently we might have as many different kinds of cases as there are permutations of four. Moreover, the amount of development of any one of these lesions, in any case, may vary from a slight to an extreme degree. Thus we have the large class of cases which have long been known under the general and indefinite term "strabismus."

In nearly every such case, when a close study is made of the condition, we find that some one lesion predominates as the most important cause of that deviation.

Our object at present, therefore, is to see how these four separate lesions are usually combined with each other. It is convenient to take them up in the same order in which we have already studied them, and considering each in turn the predominant lesion, to inquire which other lesion or lesions combine with it to produce a deviation.

§ 1. **Deviations Due Primarily to Muscular Lesions.**—Of this, but little can be said for the reason already given—that so few examinations have been made of the condition of the muscles, either on the living or the dead subject, in cases where deviations do exist.

Such data as we have, however, indicate beyond question

that an abnormal condition of the extraocular muscles is in many cases the underlying cause of deviations. Evidently, therefore, when such a condition does exist, and there is also present an ametropia or an imperfect retinal perception or some opacity of the media, the tendency towards a deviation is intensified in proportion to the extent and importance of these other lesions. This phase of the subject offers apparently one of the most fruitful fields of investigation.

§ 2. **Deviations Due Primarily to Ametropia.**—This includes our largest or second largest group of cases. The most frequent accompaniment of the ametropia is some imperfection of the perceptive apparatus in one eye or both. The symptoms vary, of course, according to the amount of imperfect perception, or to the presence of some obstruction in the media, or especially with the peculiarities in the condition of one or of another group of muscles. These determine not only the direction of the deviation, but also to a considerable extent its degree. Repetition can be avoided by considering these deviations in connection with those referred to in the following section.

§ 3. **Deviations Due Primarily to Retinal Imperfections.**—Many students consider this the largest class with which we have to deal. Undoubtedly it is the predominant lesion in a very large proportion of our cases. Most frequently of all do we find it associated with hypermetropia, the two together producing a deviation inward. That is perhaps the most frequent combination of conditions which, with others, are included by most writers under the general term convergent strabismus or squint. We do not know, however, to what extent imperfect perception or lack of the fusion faculty is really a predominant cause. Thus far we lack sufficiently careful studies of these cases. It is easy to find records of thousands of cases of convergent strabismus or divergent strabismus; we have also records of operations upon hundreds of them; but we have to search the literature to find even a few cases in which painstaking measurements have been made of the entire field of vision of the ametropia after the use of atropin, of the field of fixation, and of similar details. The reason is principally, that with young children

it is often impossible to obtain very accurate data. But the patient and careful study of even a score of such cases would be of more value than a collection of the evident symptoms in a hundred or even a thousand of them.

What we need are intensive, not extensive, studies of this point. Concerning this class there is nothing further to be said after the study which has just been made of the deviations due to imperfect perception alone.

We should, however, direct our attention to a very important condition, to which much study has been devoted—amblyopia ex anopsia. In it we have two distinct elements—the amblyopia and the deviation, which may be due to some other lesion. This combination of causes brings that condition into the class we are now considering.

As an amblyopia is so often met with in connection with a deviation, the question long ago arose whether the amblyopia is cause or result. In other words, does amblyopia from non-use ever exist? Any one who will take the references given in the bibliography as starting-points will find many long articles—almost volumes on this subject. But in this question, as in many others, the clouds of theory have been dissipated by the clear light of a few clinical facts.

These indicate that amblyopia from non-use is quite common. The validity of this conclusion will be seen when different cases of this kind are arranged in groups. Thus we have:

(*A*) Development of an amblyopia with non-use. Examples of this sort are rare, but one or two have fallen into the hands of careful observers. Thus Roosa (B 1386, p. 549) reports the case of a boy seven years old, who had no squint, but a hypermetropia of four diopters, which when corrected gave him normal vision. Subsequently the child returned with an esotropia, and the vision then in the deviating eye was reduced to twenty-one hundredths.

(*B*) Improvement of an amblyopia with use of the eye. There are now quite a large number of cases on record of heterotropia, in which, when the patient was first examined, the vision of the fixing eye was good, but the vision of the deviating eye more or less imperfect. Each of these patients

lost the good eye by accident, or inflammation; the imperfect one was then of course brought into constant use, when the vision began to improve and continued to improve until in some of the cases it became almost normal (B 1372). Only recently I have seen a case of this kind. The patient had had esotropia. The position of the axes was corrected by operation, but still one eye remained decidedly amblyopic. The better eye was injured at Baden Baden, and was removed by Dr. Pagenstecher, and within a year after the accident rough tests showed that the vision of the remaining eye had nearly doubled.

§ 4. **Deviations Due Primarily to Imperfections in the Refractive Media.**—Of these also, there is but little to be said after the consideration given to them as the sole cause of deviations. Consequently they are mentioned merely for the sake of completeness.

§ 5. **Treatment** of deviations due to two or more lesions. If in a given case the diagnosis has been made with sufficient exactness to show what is the predominating, and what are the secondary lesions, the treatment follows naturally from what has gone before. It might suffice therefore simply to observe that the treatment depends upon the form of the lesions and the degree to which each is developed in any given case, and end this section with that statement.

But a word should be added in view of the fact that more or less imperfect perception of the retina and also some hypermetropia are so frequently present. For many of the text-books give a certain routine of what is usually termed the "treatment of strabismus." It is the plan followed by many a practitioner of experience. The advice for all cases, briefly expressed, is to correct the ametropia, improve the amblyopia, and exercise the insufficient muscles. Probably we would all agree that this is a good plan of treatment for an average case. But the objection to it, and to all such advice, no matter whence it comes, is that, if applied indiscriminately and without modification for each case, comparatively little good results. If an exact diagnosis is made in each case, that tells us how this plan should be varied, and to what extent. As long as we rest content with an indefi-

nite diagnosis like that of strabismus, and practice a routine treatment in a routine fashion, no progress is made. When, however, we learn to recognize the lesions which cause the deviation and to estimate their relative importance in each separate case, then, and not until then, do we make progress in our knowledge and treatment of this large and important class of cases.

SUMMARY OF PART II.

Since the plan pursued in studying heterotropia is quite similar to that followed with regard to heterophoria, the summary at this point can be brief.

Our first endeavor was to understand the meaning of the terms employed. As the words "strabismus" and "squint" are quite indefinite, it seemed preferable to call the subject of our study non-paralytic deviations or non-paralytic heterotropia. Considerable attention was given to the different methods of measuring these deviations, most of them being described and illustrated. We endeavored to keep in mind the fact that the deviation is only a symptom which may result from any one lesion or from several lesions combined.

We therefore considered in turn four of those lesions, or rather kinds of lesions, which tend to produce deviation of the visual axis in one direction or the other. They are due to:

(1) Abnormal muscles;

(2) Ametropia;

(3) Imperfect retinal perception;

(4) Imperfections of the refractive media;

(5) Also several secondary causes which, with one exception, are usually of slight importance.

We endeavored to learn the nature of each of these more important pathological conditions, its symptoms (in addition to the deviation), how it produces a deviation, and in general its treatment. In other words, we studied each of these lesions as we had studied before each factor in simple imbalance.

Having thus obtained an idea of four lesions which could produce deviations, it was comparatively easy to see how two or more combined in the same pair of eyes had a like effect.

It is only a question of what those lesions are in the individual case, and also to what extent which one happens to be predominant, and the other secondary.

We found that imperfect perception of the retina with ametropia is the most frequent combination of lesions which produce a deviation. For this, the ordinary non-operative treatment is to correct the ametropia, to improve the amblyopia, and to strengthen the weaker muscles. But to follow this as a routine plan we also found neither scientific nor satisfactory. In each case the different causative lesions are to be clearly recognized and the treatment varied accordingly.

PART III.

ACTUAL DEVIATIONS DUE TO LESIONS IN THE BRAIN OR IN THE NERVES.

CHAPTER I.

DEFINITIONS AND PRELIMINARY CONSIDERATIONS.

§ 1. **Definitions.**—The deviations which we are now to consider are due more to relaxation of one muscle or group of muscles than to contraction of the opposing muscle or group of muscles. They are essentially of a paralytic nature. They are forms of paralytic heterotropia. It is true that pathological conditions in the brain or in the nerves occasionally do produce not a relaxation but a contraction of the ocular muscles. We have, however, no reliable means of recognizing such pathological conditions except by the hypertrophy of the muscles which results when the condition has lasted a long time. Therefore this class of deviations, although due to pathological conditions in the brain or nerves, has necessarily been considered in the second part of these studies, among deviations which are non-paralytic.

The terms employed to describe different forms of ocular paralysis require a word of comment.

The name "ophthalmoplegia" was revived by Hutchinson in 1878. He described "ophthalmoplegia interna" as a paralysis of all the nerve fibers supplying the tissues on the interior of the globe, while the term "ophthalmoplegia externa" was used to designate those cases in which "all or most of the muscles which move the globe" were affected. Thus ophthalmoplegia externa and interna, or its synonym

ophthalmoplegia perfecta, may be unilateral or bilateral (B 1483).

This nomenclature was accepted in general by Mauthner in his lectures on this subject, and though he modified the terms somewhat they have generally been adopted (B 1451).

The difficulty is, however, that English writers constantly use the terms "internal" and "external" not with regard to the globe of the eye, but with reference to the internal and external recti, or else the position of the globe itself. The French, following Charcot, use the term "migraine ophtalmique," for paralysis of the third nerve, especially in the more acute or periodic form, whether that be an ophthalmoplegia externa or interna, while in English we use the term migraine rather to describe headaches or hemicrania (B 1484–1487).

In order to avoid this confusion it is better to discard the terms "ophthalmoplegia" and "migraine" entirely in this sense, and to speak of the partial or total paralysis of whichever nerve may be affected.

When, in addition to affections of the extraocular muscles, accommodation is impaired, we should specify that fact.

It is true, this is rather cumbersome, but it is the only way to rid ourselves of the existing confusion in the nomenclature, to clarify our ideas, and enable ophthalmologists to understand each other satisfactorily.

§ 2. **The Paralyses are Important, but our Ignorance of them is Great.**—In spite of the multitude of cases of this kind which have been reported, we have comparatively few records of post-mortem examinations showing even the macroscopic condition. In only a part of these have microscopic examinations been made, and it is but recently that Ramon y Cajal and others have made examinations of nerve tissues with improved methods of staining. Accordingly, when the literature is sifted we find that a large part of it must be discarded as worthless. Until, therefore, more post-mortem examinations are made with microscopic studies according to the recent methods, a chapter on the paralyses must deal principally with methods of diagnosis, with

a few frequent causes, and altogether be brief in comparison to its importance.

§ 3 **Plan of Study.**—As very much the same plan must be followed in arriving at a diagnosis of any paralysis of the ocular muscles, and as the causes which produce them, and therefore their treatment, are very similar, we shall consider the paralyses as a whole. For that purpose we shall find it convenient to ask first what symptoms may occur in any form of paralysis, and then simply note those symptoms —especially the forms of diplopia which belong to changes in special nerves. After that we can observe the causes of paralyses in any or all of these nerves, and finally and very briefly glance at the treatment.

CHAPTER II.

SYMPTOMS AND DIAGNOSIS.

DIVISION I.

SYMPTOMS.

§ 1. **Objectively** we have:

(*A*) The deviation itself. The direction and extent of this are determined by the tests already described for measuring non-paralytic deviations.

(*B*) The arc of rotation is less than normal in the direction of the paralyzed muscle.

(*C*) The secondary deviation is greater than the primary. The explanation usually given of this phenomenon is simple, and is probably the correct one. It assumes, for example, that when a nerve impulse is sent simultaneously to the abductors on the right and to the adductors on the left side, that impulse is, as it were, equally divided between these two groups of muscles. If the impulse cannot be expended upon the abductors on the right side, the balance thus left over is expended upon the adductors of the left side, making the secondary deviation greater than the primary. The direction of the secondary deviation is toward the affected muscle.

(*D*) The position of the head is altered. In order to avoid double vision the head instinctively turns toward the affected muscle. We shall have occasion to refer to this again when studying more in detail the paralysis of special muscles or groups of muscles (B 1468–1476).

(*E*) When the fibers of the third nerve which supply the internal rectus are affected, naturally the lifting power of that muscle is lessened in proportion to the degree of the paralysis.

(*F*) Photograms of the lateral movements show these to be

usually irregular or limited. An example of the irregularity is shown in Fig. 60. The patient, a boy eight years old,

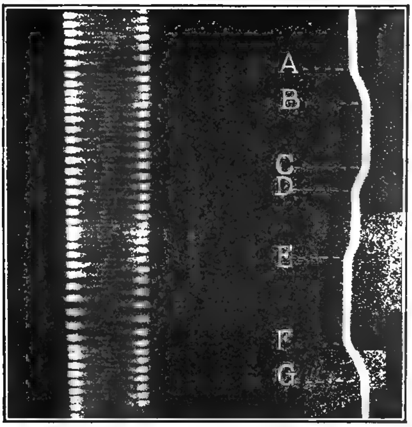

FIG. 60.—Photogram in a case of passive esotropia. This shows that the movements of the globe are slightly irregular, but approach the normal type.

had an esotropia of 16 degrees. The arc of rotation outward was recorded as 20 degrees beyond the primary position, but the motion toward the outer limits was exceedingly irregular.

In this photogram, between A and B the eye swung inward, and after a short period of rest began to turn outward at C. But in doing so it made a halt at D, and then rested between E and F. After a halt there again it swung inward to G.

The photogram Fig. 61 shows the motion present in almost complete paralysis of the third, and also of the sixth nerve. The lateral motion was much limited, and as a result we have a short swing from without inward, a period of complete rest, and then a short but regular swing again back to the original position. If there were no motion of the globe, of course the reflection from the cornea would not move at all, and the photogram would show simply a vertical line. This is an approach to that condition.

(*G*) Diagnosis of paralysis of the third nerve by galvanic reaction of the levator palpebræ.

Recently attention has been called to the fact that paresis or paralysis of the third nerve could be recognized by the galvanic reaction in cases in which ptosis is also a symptom.

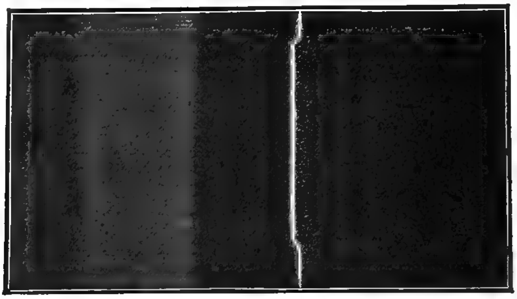

FIG. 61.—Photogram in a case of almost complete paralysis of the third and also of the sixth. This shows very slight freedom, and little or no irregularity in the motion of the globe.

When such a paresis exists, the reaction time of the affected lid is perceptibly longer than that found on the unaffected side. This method, first proposed by Salmonson, is apparently of value for the early recognition of paralysis of this nerve, but like the photograms, it requires suitable apparatus properly used, and therefore its practical value is somewhat limited (B 1461).

§ 2. **Subjectively:**

A. Diplopia. As the images in the two eyes do not fall on parts of the retina which correspond to each other, double vision results. That is evident. But it is not so easy to understand just the form which the diplopia assumes when different muscles are affected. Indeed, this is a matter which presupposes a knowledge of the anatomy of the muscles and their physiological actions, singly and together.

B. Giddiness is another symptom of ocular paralysis, apparently the effect on the brain of the diplopia. It is most marked in the acute stages and when the vision in each eye is nearly or quite normal (B 1465).

C. Unsteady gait is usually considered a direct result of the diplopia and indeed a part of it. When the figures in a

carpet, for example, are double, a patient is uncertain where to step, and if one of these sets of figures seems nearer than the other, he is apt to lift the feet too high or to stumble when taking a step.

The diplopia, however, does not explain all forms of unsteadiness of gait. In most cases the cause which has produced the ocular paralysis and the resulting diplopia has also caused a loss of coordination in the muscles of the extremities. A familiar example of this is the double vision and the staggering gait of a drunken man. Diplopia, moreover, is usually found only in acute forms or in the early stages of the disease, and usually disappears, although the deviation of the globe may persist.

§ 3. **Summary of the Symptoms.**—It is desirable to summarize these symptoms for convenience in finding promptly which muscle is affected. Thus

(*A*) The primary deviation is directed away from the affected muscle, while

(*B*) The secondary deviation is toward that muscle, but

(*C*) The face turns to the side of the affected muscle.

(*D*) The diplopia is

(*a*) crossed when either eye turns outward,

(*b*) homonymous when either eye turns inward, and

(*E*) Vertical or oblique deviations produce corresponding forms of diplopia.

(*F*) When either eye turns inward, the diplopia

(*a*) increases as the object recedes, and

(*b*) decreases as the object approaches.

(*G*) When either eye turns outward, the diplopia

(*a*) increases as the object approaches, and

(*b*) decreases as the object recedes.

§ 4. **How to Locate the Paralyzed Muscle.**

It is one thing to learn theoretically what signs and symptoms may accompany different forms of paralysis, but quite a different matter to determine satisfactorily in a given case just which group of muscles or which muscle is affected. In extreme cases the deviation of the eye and position of the head proclaim the condition the moment the patient enters the room. But often the axes seem parallel and the position

of the head normal. These cases are apt to prove a stumbling block to the very elect, unless some definite plan is followed in the examination. For this purpose the simplest is, as usual, the best. It consists in asking ourselves:

First, which group or which class of muscles is affected, irrespective of which eye it is. That is to say, is the fault with the dextro-or lævoductors, or with what other ductors? (Vol. I, p. 188.) Thus we ask first where the double images are in case they can be recognized, and in which direction they approach or recede from each other.

Second, we inquire to which eye this affected group of muscles belongs. For this, the testimony furnished by the double images is useful, but still more important is that given by the perimeter or tropometer.

Third, we should determine which muscle or muscles of that group are especially involved. In all of these tests we should be especially careful to recognize faults in the power of convergence or, if necessary, the power of relative convergence should be accurately measured. Without some such definite plan of procedure it is often practically impossible to ascertain which of the muscles is defective. It is necessary also to diagnose any paresis or paralysis of the ciliary muscle which may exist. This is mentioned here rather for the sake of completeness, the various tests for it having been already considered in connection with the anomalies of the accommodation (heterocykinesis).

CHAPTER II.

DIVISION II.

AIDS TO DIAGNOSIS.

§ 1. **Ophthalmotropes.**—While the ophthalmologist of experience has less difficulty in arriving at an exact diagnosis than the beginner, it is often convenient and sometimes neces

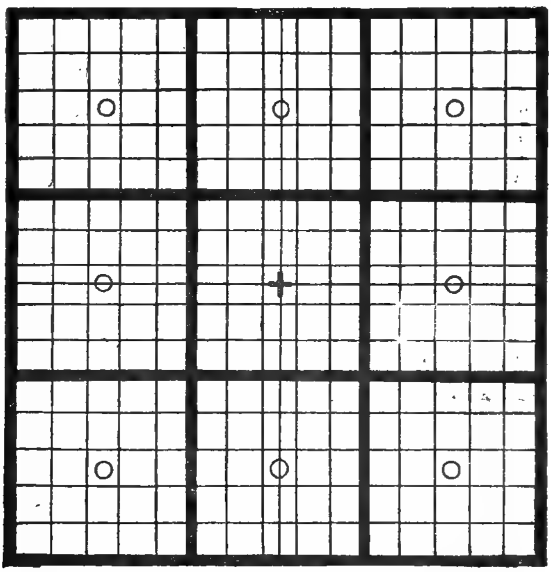

FIG. 62.—Reduced form of chart on which to record positions of single and double images.

sary to clear thinking to have at hand an ophthalmotrope with which to imitate the deviation found in the eyes of the

patient. Even the rubber ball (Vol. I, p. 181) is of some assistance, and the more complete ophthalmotrope (Vol. I, p. 184) has proved of real value. With that, it is possible to see from the pictures on the ground-glass plate the position of the retinal image in one eye or both.

§ 2. **Charts** of the areas of double and single vision are especially useful. These are based upon the principle already referred to of the difference in the relative positions of the double images. As these images unite in one part of the field of fixation and separate in another, we have long had these representations of the fields of single and double vision. The usual method of making the chart is to consider the space

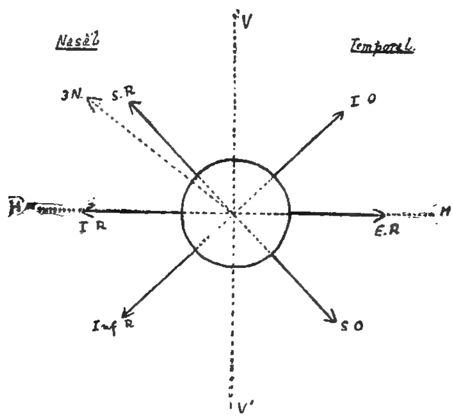

FIG. 63.—Chart of R. Bruce Ferguson for showing the positions of the double images with different movements of the eye.

in front of the patient as divided into nine equal squares, and to have the patient fix a point in the centre of the central square. I have found it rather more convenient to subdivide each of the squares into smaller ones, and also to indicate with a small circle the centre of each of the larger squares. These will be copied subsequently, when giving the fields of diplopia in different paralyses. The charts which are ordinarily used are divided thus into nine squares, and are therefore given here, (Fig. 62) even though the form of the chart suggested by Duane (p. 191) is more exact.

A simple and excellent plan for showing the position and rotation of the false image in paralytic diplopia has been suggested by R. Bruce Ferguson (B 1479)—Fig. 63.

This represents a transverse vertical section of the eye, taken in front of the equator, or, what is the same thing, it may be taken to represent the pupil of the eye. It represents what is seen by the patient's own right eye. The diagram shows the following points:

(*A*) The direction of action of the muscles of the eyeball.

The arrows show the direction in which the pupil turns, or in which the eye will look when acted upon by the individual muscles.

(*B*) The primary deviation of the eye in paralytic squint.

If any muscle is paralyzed, the eye will of course look in the direction opposite to that in which the paralyzed muscle normally acts.

(*C*) The position of the false image in diplopia.

The false image is always displaced in the direction of the paralyzed muscle—that is, it is displaced in the direction in which the arrow points. There are other advantages of these charts, which it is unnecessary to detail here. In using them and all like them, the surgeon should imagine himself in the position of the patient, in order to interpret most readily the significance of the false image. The failure to do this has led to endless confusion of description, and has complicated the subject to such an extent that in some text-books it becomes wellnigh incomprehensible. While the surgeon of experience may consider himself quite superior to such aids to diagnosis, there are few who at times do not find them very helpful.

CHAPTER II.

DIVISION III.

DIFFERENTIAL DIAGNOSIS BETWEEN THE NON-PARALYTIC (ACTIVE) AND THE PARALYTIC (PASSIVE) DEVIATIONS.

When dealing with latent deviations, frequent references were made to the importance of distinguishing whenever possible between those which are active and those of a passive character. In the part which relates to operations, we shall see that the decision as to whether to make a tenotomy or an advancement depends upon whether a given actual deviation is of an active or passive character. The more detailed consideration of this differential diagnosis has therefore been deferred to this point, where we are better acquainted with the symptoms of deviations which are also of a passive character.

The question before us is to determine, if possible, whether a given deviation is due to abnormal contraction of one group of muscles or to abnormal relaxation of the opposing group, or to both of these causes. An illustration will make clearer the shades of meaning. If a pair of scales have a weight of fifteen grams on each side, the scales balance. Let us suppose these represent the force of the adductors and abductors of the right eye. If we add one gram to the scale on the left side, that would correspond to an increase in the force of the adductors and would represent an active esophoria.

If, however, the weight on the left side remains fifteen grams, and we remove one gram from the right side, the scale still tips in the same direction. That corresponds to a passive esotropia.

If, finally, we place sixteen grams in the left-hand scale and

fourteen in the right, the scale tips to the same side a third time, but it is due as much to the additional weight on the left side as to the reduced weight on the right. This corresponds to a composite or mixed form of esotropia.

This simple and crude illustration may seem superfluous, but it assists in defining the diagnosis which we are attempting to make. The fact is, that in most of the variations with which we have to do, the muscles in the direction of the deviation and also the opposing group are abnormal. But esotropia of early life which is associated with ametropia is often of the active type, while the various paralyses in the early stages belong clearly to the passive type.

In a case of evident paralysis, the differential diagnosis is easy enough. If the rotation in any direction is greatly limited, if the secondary deviation is greater than the primary, or if binocular vision or any other of the more evident symptoms of paralytic deviation are present, its passive character is clear. But very frequently none of the simple or ordinary tests will show whether a given deviation is principally of an active or principally of a passive type, or whether there exists excessive contraction of one group of muscles *together with* insufficient contraction of the opposite group.

An active deviation is distinguished from the passive type by the following characteristics:

§ 1. **The History of the Case.**—If the deviation has appeared suddenly—certainly if it is in a person past early childhood, that points to some sudden loss of power—in other words, to a passive type. But if it appears in very early life it is more apt to be of an active, or of a mixed type.

§ 2. **The Refraction.**—Hypermetropia in any of its forms means of course abnormal effort of the ciliary muscles to produce a clear focus, and that in turn causes excessive action of the internal recti. Most of these deviations are of the active type, at least in the early stages. On the other hand, myopia necessitates less action of the ciliary muscle, and therefore is apt to accompany a passive exotropia. But as the length of the external rectus and the grasp which it

has on an elongated globe allow it to act at an evident advantage over its opponent, some of the deviations outward with myopia are of an active character.

§ 3. **Diplopia.**—When this is present, and certainly if it has existed but for a short time, it is natural to expect that the deviation is due to a paralytic condition of one group rather than any sudden change in the condition of the opposing group.

§ 4. **Action of Prisms.**—When diplopia is present or when it can be elicited, the minimum and also the maximum power of adduction or abduction give important evidence as to the action of the adductors or abductors. As the relative force of the muscles shown by prisms has been considered in detail already, this point need not be elaborated (Vol. I, p. 298).

§ 5. **The Arc of Rotation.**—The limits of this arc and the behavior of the eye in reaching it furnish the most important evidence which we have in differentiating between an active and a passive deviation. In regard to these measurements we should understand that proper appliances, properly used, are essential to constant results.

In order to measure the arc of rotation we need a perimeter with electric light, preferably also with telescope attachment, and we frequently need a tropometer. Most of all, however, we require abundant time and patience, and a determination to ascertain facts, not simply to finish some sort of an examination in the shortest time possible. It must be remembered also that the behavior of the eye as it attempts to reach the limits of the arc is almost as significant as the number of degrees which the globe can travel (Vol. I, p. 199). One who is accustomed to these observations recognizes easily the prompt and certain swing of one globe to its desired position, as different from the wavering and halting motion of another globe, even though they may both ultimately traverse the same number of degrees.

(*B*) In active heterotropia the arc of rotation is greater than normal in the direction toward which the visual axis turns. But in the pure types the arc is also at least relatively normal in the opposite direction. This last is a most

important point in the differential diagnosis. For evidently, if the arc is limited in the opposite direction, that indicates at once that the deviation is also of a passive character. Thus, the perimeter and the tropometer together often show that an esotropia of long standing has an excessive arc of rotation inward and an insufficient arc outward. The deviation is both active *and* passive.

§ 6. **The lifting power** of the adductors also indicates whether a deviation in the horizontal plane is of an active or a passive character. In making these measurements another element must be taken into account besides the actual lifting power. This is the behavior of the eye. Sometimes it lifts a given weight promptly or possibly the same weight slowly, hesitatingly, and with a twitching movement. Unfortunately we have no means thus far of measuring the lifting power of the abductors. This is an evident imperfection in this class of measurements, but it is better to know even approximately the force of a group of muscles and how that corresponds with the normal, than to disregard such data entirely.

§. 7. **Photograms** also assist in arriving at this diagnosis. It is evident that the elements which constitute the motion from side to side give no indication in themselves as to whether a deviation is due to a fault in one group of muscles as compared with the opponent. For example, in a case of esotropia suppose the swing inward is more rapid than the swing outward, that the extent of the arc inward is longer than the arc outward, and that the globe remains a longer time near the inner than near the outer canthus. All of these conditions may be present when there exists either an excessive power of adduction or an insufficient power of abduction—or both. But when any or all of these elements are taken in connection with other findings they furnish corroborative evidence which should not be left entirely out of account.

CHAPTER III.

PARALYSIS OF THE THIRD NERVE.

In studying the paralyses of the third nerve, it is best to obtain first a mental picture of such a condition in its most complete form, and then to see what the variations are from that type as manifested in the acute and recurrent forms. That will lead us to a consideration of the pathological anatomy and to distinguish the nuclear paralyses from those due to lesions in the cortex or the basal portions of the brain. Finally we shall glance at those peripheral paralyses which involve separate branches.

§ 1. **Complete Paralysis.**—Let us look at the clinical picture presented by a person suffering from complete paralysis of the third nerve (Fig. 64).

Fig. 64.—Complete paralysis of the third nerve, right side, usual form.

The upper lid, having lost its power of contraction, falls inertly over the globe, which it covers more or less completely. The eyebrow also droops and increases the asymmetry of the face. When the patient tries to lift the lid he raises the eyebrow on that side by contracting the muscles of the forehead, but cannot succeed in uncovering the globe.

Sometimes, in order to succeed better, the sound eye is closed. In extreme cases the upper lid falls so far over the lower that at first glance the fibers of the orbicularis seem to be forcibly contracted (Fig. 65). When the drooping lid is

FIG. 65.—Extreme case of paralysis of the third nerve, upper lid drooping over the lower.

lifted by the finger, the globe is found to be turned far outward. Its motion is usually much limited or it is practically immovable.

If the patient is told to look down, he can do it to a certain degree, as a result of the action of the superior oblique. Usually the pupil is dilated and does not react to light, nor to any effort of convergence. Indeed, the eye is in the same condition as when adjusted for the far point, while the divergence results, of course, in a crossed diplopia. Such is the picture which we find in cases of complete paralysis of the third nerve. In the varieties of partial paralysis we have a part of these symptoms present, but differing from each other in the time of their appearance or in their degree.

§ 2. Varieties of paralysis of the third nerve according to the character of the attack.

(*A*) Acute paralysis. Cases are by no means unusual in which a paralysis of one or more branches of the third nerve appears in a person otherwise perfectly well, and within a few days the disease develops in a most pronounced degree. The cause of this is often difficult to recognize, but usually there is a hemorrhage or effusion near the nucleus, or in some other portion of the brain intimately related to it. We shall see that other causes besides disturbances of the cir-

culation or effusions produce acute paralysis of this nerve, as, for example, grippe, diphtheria, or some of the eruptive diseases (B 1513–1517). Although these cases are obscure, their importance is evident, for, whatever the cause, it may also produce disturbances even more serious in other portions of the brain. When, however, it happens, as in certain instances, that the acute symptoms are limited to one or two muscles, it is fair to conclude that the effusion, if such it be, is not extensive, and the prognosis is therefore comparatively favorable,—much more so, at least, than where the development of the symptoms is slow.

(*B*) Recurrent paralysis. The same causes which produce a single acute attack of paralysis may of course produce the same result in the same muscles or group of muscles a second or third time. These cases are curious, and fortunately rare.

A good type of the class is given by de Schweinitz (B 1524). This was of a woman of thirty, whose attacks began when a child of about a year and a half, and continued at intervals subsequently. The causes of such repeated attacks are always obscure, although it is probable that, like other acute forms, they are more or less directly connected with the vascular system. When occurring in certain infectious diseases of the malarial type, the indications are that they are due to the germs which ripen at intervals and flood the system with their toxins. In two cases of recurrent paralysis which have come under my observation, the attacks grew gradually more marked, and both patients died soon after an onset of unusual severity. The literature of recurrent motor oculi paralysis previous to 1894 has been admirably epitomized in an article by Jeffreys (B 1486).

He gives a careful digest of thirty-nine cases, and says of them: "The attack in the great majority of cases begins rather suddenly with nausea and vomiting and severe unilateral pain in the head . . . soon after the onset of the pain, paralysis of the third nerve has ensued. In a good many cases the pain has persisted after the onset of the paralysis . . . after a varying period of one to two days to six months, the paralysis has disappeared, either wholly or

in part. In fifteen cases the attack lasted less than a week, in six cases from a week to a month, in seven cases from one to three months, and in two cases over three months." He also says that the prognosis must be considered grave; three cases out of the thirty-nine which he collected resulted fatally, and thirteen showed an increase in the severity of the symptoms in successive attacks.

(*C*) Chronic paralysis of the third nerve is the most common form, and that which more particularly interests us, for, as we shall see presently, the type with which we have the most to do is that in which first one branch of the third nerve is affected, then another and another as the disease advances, the case declaring itself thus as one of nuclear paralysis.

Pathological Anatomy.—Evidently the lesion which produces this condition may be in the brain at its base, in the orbit, or in the terminal filaments. If cerebral, it may be in the nucleus itself, in the cortical portion, or in the fascicular portion, and so on with the other details. It tends to clearness to arrange the location of these lesions in tabular form, and the following modification of a table proposed by Collins and Wilde may prove useful (B 1485).

I. Cerebral.	(*A*) Nuclear involving the	(*a*) Levator palpebræ.	
		(*b*) Other extraocular muscles.	Internal rectus. Superior rectus. Inferior rectus. Inferior oblique.
		(*c*) Intraocular muscles.	(*a*) Partial (Argyll-Robertson pupil, iridoplegia). (*b*) Total (cycloplegia).
	(*B*) Cortical		
	(*C*) Fascicular		
II. Basilar.	(*D*) In the peduncles.		
	(*E*) In the cavernous sinus.		
III. Orbital.	(*F*) Involving any of the branches.		
IV. Peripheral.	(*G*) Involving any of the branches.		

Unfortunately, however, our data concerning the pathology of the third nerve are far from complete. We find in the literature many cases in which various symptoms have been observed accurately, and some in which the macroscopical and even the microscopical conditions have been worked out in detail, but what we lack is co-operation in these two fields of investigation. It should be remembered also that the existence of a lesion in a certain portion of the brain

does not mean that this is necessarily the cause—at least, not the only cause. For example, syphilis may produce changes anywhere in the brain, and also produce lesions in different nerves at the same time. But an arrangement of the forms of paralysis of any nerve according to the locality of the lesion gives a working basis, and in many cases explains very satisfactorily the clinical symptoms. Let us therefore consider these varieties in the order given in this outline.

I. Cerebral Lesions.

(*A*) **Nuclear paralysis** of the third nerve. The type of this is usually described as the slowly progressive form, such as is seen in tabes or in some cases of syphilis. It may show itself in the muscles on the outside or on the inside of the eye, affecting one or two branches at first, then others, and in a greater degree, and finally all the muscles supplied by the third. But we naturally ask what symptoms or sequence of symptoms can be considered as indicating that a given paralysis is of nuclear origin? It must be confessed that this is not easy to determine, and in many cases is quite impossible, especially in those mixed types in which the development of the symptoms cannot be followed with exactness.

But when certain cases are carefully observed at an early stage, we find that the order in which the paralysis develops in the different muscles accords fairly well with the arrangement of the different groups of cells which constitute the nucleus of the third nerve (Vol. I, p. 97). Thus:

First, when the different muscles are affected in the order in which the groups of cells are arranged, either from before backward, or from backward forward, or in any other special direction, there is a reason to suspect that the lesion is in the nucleus. It should be understood that really typical cases of that sort seldom occur, but any approach to that type is suggestive.

A second diagnostic point in the nuclear form of paralysis of the third nerve is that it is not associated, at least not in the early stages, with other paralyses, unless perhaps of the fourth.

Third, although the paralysis may show itself at first only in one eye, it is apt to develop later in the other.

Fourth, the absence of headache has long been considered one of the indications of nuclear paralysis.

In the hurry of routine practice we are too often satisfied with making a diagnosis simply of paralysis of the third nerve, but a more painstaking examination by the methods already described, especially by measuring the fields of single and double vision, very often indicates that certain branches of this nerve are affected to a much greater extent than others. Indeed, we have not infrequently one or two muscles much involved, while others remain apparently normal. If, therefore, it were the habit of most clinicians to ascertain just which muscle is paralyzed, we should of course have a better idea as to which group of cells in the nucleus is probably affected, especially if subsequent examinations showed that other branches of the nerve became gradually more and more involved, and also if the groups of cells supplying these other branches were contiguous to the first group. But it should be repeated that it is often impossible to diagnose nuclear paralysis with absolute certainty, especially when misleading complications are present.

(*a*) Paralysis of the levator palpebræ (of nuclear origin). This condition is mentioned with the nuclear paralysis, because it exists when the corresponding group of cells is involved. The location in the nucleus of the cells which supply the levator palpebræ has been corroborated by an interesting and complete observation made by Siemerling (B 1566).

(*b*) A paralysis often develops of one or two of the extraocular muscles which are supplied by the branches of the third nerve while other muscles remain normal.

Mauthner (B 1451) quotes a dozen or more well marked cases in which, with paralysis of the extraocular muscles, the reaction of the pupil remained practically perfect. If we recall for a moment the arrangement of the cells in the nucleus, we remember that the group which presides over accommodation lies in the center and the anterior part of the nucleus. If, therefore, accommodation depends upon this group alone,

then in the class of cases now under consideration the cells in all the groups surrounding this central portion of the nucleus must have been affected, leaving intact only that central group. This is so improbable as to indicate that in addition to this central group of cells in the nucleus, there must be another which has the same or a similar function.

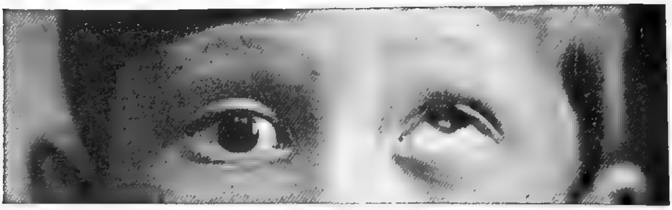

FIG. 66.—Paralysis of inferior rectus.

Very frequently, of course, the lesion affects only a part of the nucleus of the third. Fig. 66 shows a case in which only the left inferior rectus is involved.

The fields of single and double vision are characteristic, in recent cases in which a paralysis has occurred in any one of the extraocular muscles. These fields were mapped out long ago, and are shown in most of the text-books, the illustrations differing from each other only in completeness of detail. When any one of the muscles supplied by the third nerve is paralyzed, the resulting diplopia is such as we see in Figures 67 to 70.

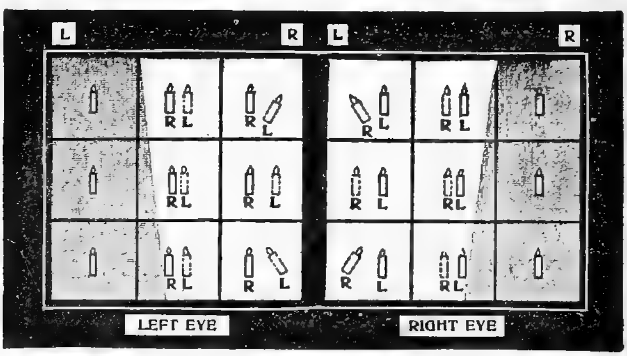

FIG. 67.—Paralysis of the internal rectus.

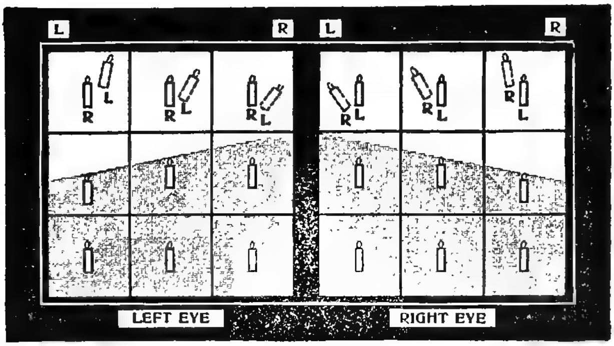

FIG. 68.—Paralysis of the superior rectus.

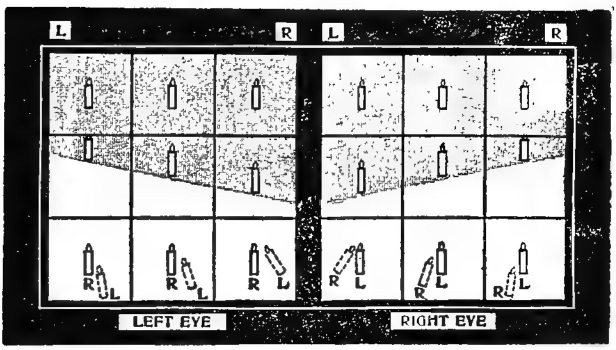

FIG. 69.—Paralysis of the inferior rectus.

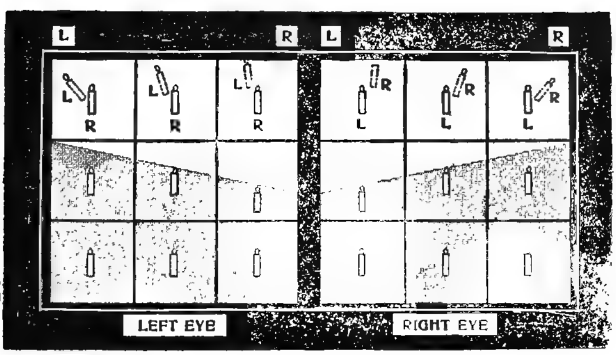

FIG. 70.—Paralysis of the inferior oblique.

The positions of the double images do not always agree with what we might at first expect. Thus in paralysis of the right internal rectus, the line which separates the area of the single from that of double vision is not exactly vertical, and is also somewhat to the right of the central point of the field. If the paralysis were complete, and if the internal rectus were the only muscle which turned the eye inward, then the right globe would swing as far outward as the outer canthus. But we know that such a complete rotation of the eye is not usual, because the superior and inferior recti also rotate the globe inward. If they were to rotate it inward as far as the median line, the line of division between the single and double areas in the field would pass through the central point of that field. It is usually impossible, however, for them to do this, hence we find the division between the areas of single and double vision does not reach the center of the chart.

We can account in a similar way for the obliquity in the line of demarcation. For the apparent positions of the double images are influenced by the false torsion seen when the axes are parallel. If it is borne in mind that the test objects should be placed at such a distance as to exclude any effort at accommodation, the law of Listing (Vol. I, p. 274) assists us greatly in explaining apparently anomalous positions of the double images, when these are situated in an oblique position.

Thus in a paralysis of the right inferior oblique, the eye would tend to turn down and slightly inward, while the corresponding false image would appear up and slightly outward. But this in itself would not explain all of the obliquity of the false image, or the fact that this obliquity becomes greater in proportion to the deviation. It is, however, easier to understand it if we recall the obliquity which is assumed by the vertical portion of the central cross which we have used in the after-image tests when, for example, that cross is projected into the upper and external quadrant of the field of fixation (Vol. I, p. 268). The importance of the law of Listing in explaining the position of the double images can only be referred to here. Moreover, the elaboration of this point for each muscle or group of muscles is unnecessary for those who have followed the

description in the physiological part of our study of the principles governing torsion with parallel axes.

(*c*) Partial paralysis of the fibers of the third which supply the sphincter iridis (partial internal ophthalmoplegia). When considering the motion of the pupil from the physiological point of view, we obtained a glimpse of the great extent of this phase of our subject. It would be far beyond what is contemplated here to study even a partial impairment of pupillary reactions. It is only possible, therefore, in passing, to recall the well-known fact that in certain cases the pupil contracts in efforts of accommodation, but not to the stimulus of light, this being the well-known Argyll–Robertson pupil, while, under drugs like belladonna, or as the result of diseases like diphtheria, neither light nor convergence is sufficient to produce pupillary contraction.

(*B*) Paralysis from lesion of the cortex. Numerous post-mortem examinations prove that in certain cases of paralysis of the third nerve there is a lesion in the cortical portion without any corresponding changes in the nucleus. As we do not know exactly the course which the fibers take in passing from the cortex to the nucleus, nor how they are arranged on the two sides of the brain with reference to each other in order to produce associated movements, it is difficult to explain these cases satisfactorily. Still more doubtful is the conclusion when, in addition, the fourth and sixth nerve are also involved, as in most of the cases referred to by Mauthner.

We do know, however, that while in the nucleus the cells are packed closely together, those fibers which go from the cortex are much more widely separated from each other, and also that decussations exist at various points in the cortex and other parts of the brain, so that a lesion at any such point results in symptoms inexplicable but for these anatomical reasons.

(*C*) Paralysis from lesion of the fascicular portions. In certain cases the lesion is not directly in the cortex nor in the nucleus, and some writers have therefore made a special class of the paralyses which are due to lesions in the fascicular portion of the third nerve. Theoretically that is

permissible, and it constitutes a convenient pathological waste-basket for these paralyses, when the facts do not warrant us in placing them with either of the foregoing groups. We have comparatively few pathological data concerning these cases, although a good illustration of rather an unusual condition is seen in Fig. 71.

FIG. 71.—Paralysis of the levator palpebræ with esotropia.

This is a young man with epicanthus, who had, as the photograph shows, not only a decided double ptosis but also esotropia, the latter being of a distinctly paralytic character. If the lesion involved the whole nucleus of the third nerve, we would naturally expect an exotropia such as is usually seen. The only explanation, therefore, of a case like this is that the lesion affected the sixth in some part of its course, and also either a small portion of the nucleus of the third, or, what is more probable, the cells of the third which lie in some other part of the brain.

(*a*) Paralysis of the levator palpebræ (not of nuclear origin). This drooping of the upper lid in one eye or both deserves mention. When it is total, the lid may cover the globe so completely that the patient sees with difficulty, even though the head be thrown far back. Fortunately, these cases are seldom met with. In some, this ptosis is the

only sign of difficulty with the third nerve, and as the post-mortem examinations of a considerable number of cases have shown that there had existed a degeneration of the anterior lobe of the brain it was concluded by Landouzy and Grasset that there must be a special center in this region. for the cells supplying the levator palpebræ. Although that fact is not yet established, there is abundant evidence to show that there is an intimate relation between that portion of the cortical substance and the fibers which supply the levator.

II. **Basilar Paralysis.** Some writers make a distinction between the paralysis which occurs while the nerve is in the peduncles and while it is in contact with the cavernous sinus. As a refinement of pathological study this is warrantable, but for practicable purposes it is unnecessary. When a lesion occurs in one of these localities it almost inevitably extends to the other. A particularly characteristic symptom is that a lesion in this region involves all of the branches of the nerve in about the same degree. For as the nerve there consists of a single trunk, anything which affects part of the fibers would be apt to affect them all. Another symptom which points to a lesion at the base of the brain is that the onset of the difficulty is sudden. The explanation is clear if we turn to the causes of basilar paralysis. In the majority of cases these are effusions, usually of blood, after some accident which involves the base of the brain ; or an inflammation of the meninges may, either primarily or secondarily, affect the nerve trunk and in that way also constitute a lesion. Here, as elsewhere also, tumors, especially gummata, may be present, having pushed toward the lower part of the brain from an adjacent locality.

III. **Orbital Paralysis.** In rare cases we see a paralysis of the muscles supplied by the third nerve produced by some lesion primarily in the orbit. The symptoms then resemble those of the basilar form, especially by involving all of the branches in about the same degree, but, sooner or later, an additional symptom appears which proclaims that the lesion is in the orbit. The globe begins to protrude. This exophthalmus may not be noticeable if by chance the lesion is

primarily in the nerve itself, or if much circumscribed, but when there are any symptoms of paralysis of the third, and at the same time the slightest difference in the amount of projection of the eyes can be perceived, no pains should be spared to measure that difference accurately from time to time. Unfortunately that is not so easy to do. We cannot consider here the different methods which have been proposed to accomplish it. In passing, however, mention should be made of the very simple arrangement suggested by Jackson for estimating, as we can with considerable accuracy, the position of the anterior surface of the cornea. A flat strip of wood with a notch in the center is held in the horizontal plane, so that the edge rests against the external canthus of each eye or is in a line with it. The surgeon then sights along the different horizontal lines which are drawn across its upper surface and notes the one which seems to be tangent to the cornea. Other methods might also be mentioned, but that would mean too long a digression.

IV. **Peripheral Paralysis of the Third Nerve.** This is very common—especially in the branches which supply the ciliary muscle. Perhaps the most frequent variety is peripheral paralysis due to injury of the intraocular branches of the third nerve. This demands special notice for the reason that the effects of even a slight blow are often excessive in proportion to the amount of injury sustained. It is a common thing for a person to receive a comparatively slight injury to the globe with perhaps a little hemorrhage into the anterior chamber. In some cases even this symptom is lacking. Immediately after, or within a day or two, the pupil dilates, and afterwards the cycloplegia remains, unless controlled temporarily by some form of myotic. It is not easy to understand why the result of such an injury, often slight, should be so marked in some branches of a nerve, while the other branches remain intact. But such is the fact, and it is one of great clinical importance.

CHAPTER IV.

PARALYSIS OF THE FOURTH NERVE.

THIS is probably a rare affection. But it would certainly be recognized more frequently if clinicians were more in the habit of mapping out carefully the fields of single and double vision. Varieties of this paralysis, such as the acute or chronic, might be recognized, or they might be divided, according to the locality of the lesion, into those which are nuclear, basilar, etc. But as this nerve supplies one muscle only, we have no such variety of symptoms on which to base an opinion as to the locality of the disease.

The fields of single and double vision are quite characteristic and are seen in Fig. 72.

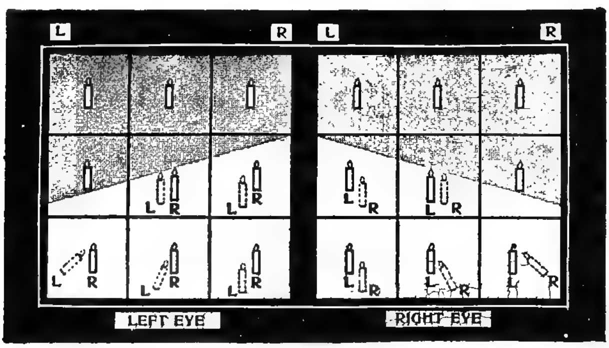

FIG. 72.—Paralysis of the superior oblique.

The causes, as far as we know, are very much the same as those which affect the third and sixth nerve, and will be considered later. Our actual knowledge of the pathology of this nerve is so limited as to make the consideration of it here necessarily very brief (B 1581–1587).

CHAPTER V.

PARALYSIS OF THE SIXTH NERVE.

§ 1. **Frequency and Forms.**—This affection occurs about as often as paralysis of the branches of the third nerve. If it were desirable to go into detail, we might call attention to the different varieties of paralyses of the sixth, as has been done with the third nerve. Thus a paralysis of the sixth may be acute or chronic, complete or partial, it being most frequent in the chronic form. The forms of paralyses of this nerve might also be distinguished by the location of the lesion, as nuclear or basilar, as has been shown occasionally on macroscopic or microscopic examination. Such an extended treatment of the paralyses of the sixth would be in keeping with the importance of the subject, but

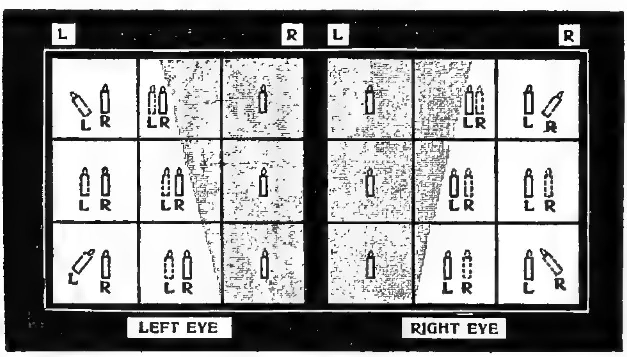

FIG. 73.—Paralysis of the external rectus.

is evidently impossible and much would be necessarily only a repetition.

§ 2. **The symptoms** are, in general, the same as those of paralyses of the other nerves, although the fields of

single and double vision for each eye are of course characteristic; these are seen in Fig. 73.

Attention should be called to the position of the head. The act of turning the head toward the affected muscle is considered by all authorities one of the diagnostic symptoms of paralysis. This, more than any one symptom, separates the actual from the latent deviations. But as, in some individuals, the head tends to turn to the right or left, especially when efforts are made at reading and other close work, this has been described as if it were something new, under the term of "dextrophoria" or "sinistrophoria" (B 1466–1467).

It is possible, of course, that in certain cases there may be a latent tendency of both eyes to turn to the right or left, but, in cases thus far described, the evidence indicates that they were ordinary cases of paresis of the sixth or certain branches of the third nerve.

Under any circumstances, if we are to follow the established custom, we must consider that the very act of turning the head in any direction, at once characterizes the condition not as any one of the phorias, but as some one of the tropias. When such an abnormal position of the head lasts for a considerable time, it is natural that the muscles which draw it in a certain direction should become hypertrophied and the opposing muscles correspondingly relaxed. This condition is one which counts for not a little in all operative procedures. For no matter how accurately the ocular muscles may be adjusted by operation, if the muscles of the neck still remain in an abnormal condition, some diplopia will remain, until the so-called habit has been overcome, or the muscles of the neck have regained their normal condition. In some cases the process may advance from torticollis to an actual scoliosis, and then of course the possibility of cure is small (B 1468–1476).

These references to so-called dextrophoria and sinistrophoria might have been made with equal propriety in connection with the paralyses of the third nerve, for it is probable that the tipping of the head to one side is due as frequently to an abnormal condition of the third as of the

sixth. Possibly also the fourth may be involved. Apparently no exact measurements have been made to ascertain definitely which group of muscles was at fault in any case thus far reported.

§ 3. **The causes** of paralysis of the sixth will be considered with the paralysis of other nerves. In passing, however, it is interesting to note in what a considerable number of cases paralysis of the sixth is one of the manifestations of secondary syphilis. As diphtheria seems to show a predilection for the cells in the nucleus of the third, which preside over accommodation, so does syphilis seem to exert a like influence upon the nucleus of the sixth nerve. The bearing of this is evident in connection with all questions of treatment. An examination of the literature indicates that paralysis of the sixth occasionally follows pneumonia (B 1603) or influenza (B 1609), and not infrequently it is associated with an inflammation of the middle ear (B 1610–1614). In a very interesting but small group of cases a bilateral abducens paralysis has been found (B 1595–1599). Unfortunately we know almost nothing of the lesion which produces such conditions.

CHAPTER VI.

PARALYSIS OF BRANCHES OF THE SYMPATHETIC.

§ 1. **Varieties and Frequency.**—It is certain that abnormal action of the sympathetic frequently affects the size of the pupil, and sometimes also the accommodation. What interests us now are the more pronounced but rare cases of marked paralysis.

§ 2. **The symptoms** were described long ago by Horner; these are:

(*A*) A contracted pupil on one side or both, which does not dilate when the intensity of the light is suddenly lessened.

(*B*) Partial closure of the palpebral fissure. We know that the smooth muscular fibers in the upper lid, described by Mueller, are supplied by branches of the sympathetic, and apparently these are affected like the fibers which go to the iris.

(*C*) In recent cases the face is often flushed on the side of the paralysis, and a thermometer or even a touch of the hand shows that there is some elevation of temperature. With this the perspiration is more abundant on that side. We also find, not infrequently, that the globe seems to be slightly sunken.

§ 3. **Pathology.**—Although our knowledge of this subject is far from complete, experiments on animals and clinical observations, especially those of Oppenheim, show that somewhere in the lower part of the cervical or in the upper part of the dorsal there is what may be called a cilio-spinal center. When this center is irritated, we have an enlargement of the pupil, pallor of the face, and decrease in the amount of perspiration, and, on the other hand, a paralysis of the cervical sympathetic is followed by the opposite symptoms. In a word, this is the probable seat of the lesion, whatever it may be.

CHAPTER VII.

CAUSES OF OCULAR PARALYSIS.

THE various classifications of the causes of ocular paralysis have given rise to no small amount of confusion. Some authors arrange these as hereditary and acquired, and others according to the disease which primarily produces the lesion, as syphilitic, diphtheritic, etc. Such classifications are very well as far as they go, but in the present state of our knowledge they are hardly more than groups according to names. When we say a paralysis is syphilitic, we simply mean that it is one of a certain group of symptoms, but the term tells us nothing of the pathology. Therefore in any such list, one case often bears no relation to the next preceding or following. Accordingly, as the etiology and pathology are intimately associated, the discussion of one may often involve reference to the other.

(*A*) Hereditary paralyses of the ocular muscles. A good example is reported by Beaumont. No less than twelve members of a family were shown, either by direct observation or by reliable evidence, to have suffered from a greater or less degree of ophthalmoplegia externa. Among them all ptosis was a prominent symptom. Of these cases he says: "The disease was never congenital, but always appeared in adult life, was slowly progressive, and never appears to have had a fatal termination. There was no Graves's disease in the families, and their characteristics were long life and troops of children" (B 1624).

Other hereditary tendencies to paralysis, especially of the third nerve, have been observed by Londe and others. Schiller reported a family in which the disease showed itself in three generations (B 1503–1510).

(*B*) Teratologic paralyses, or those due to imperfect development. Although nearly allied to the last, these cases differ sufficiently to form a group by themselves. We have seen (Vol. I, p. 96) from the experiments of von Gudden that when a muscle with the nerve supplying it is extirpated in the young animal, there results an atrophy of the cells in the nucleus which supply those nerve fibers. In the same way, there is abundant clinical evidence to show that when there is, for any reason, an arrest in the development of the nucleus, or the part of the brain from which these fibers spring, there results a corresponding paralysis or even atrophy of the muscle itself. Light has been thrown on this point by an interesting study, by Motais, on the relation between so-called infantile paralysis and the disappearance of the nucleus of the motor oculi.

(*C*) Paralyses due to infection.

(*a*) Syphilis.

Formerly it was customary to think that almost all of the ocular paralyses were of specific origin, either in the hereditary or in the acquired form. This idea has been brought into prominence by our French confrères. Thus Ricord was accustomed to say that an ocular paralysis was the handwriting of specific disease upon the eye of the patient. Fournier also, in his lectures on Syphilis of the Brain, says that at least seventy-five per cent. of the ocular paralyses are due to a specific infection. It is probable, however, that these statements give an exaggerated idea, and that they are based more upon general impressions than upon carefully arranged statistical tables.

Among the more recent studies of the changes which syphilis produces in the brain and of the manner in which it affects the muscles of the eye, special mention must be made of the investigations of Uhthoff. He gathered the histories of a hundred and fifty cases in which the diagnosis of syphilis was well established, and in which the post-mortem condition had also been recorded with more or less exactness. Out of these he found that the third nerve was affected on one or both sides, as shown by the post-mortem examination, in only fifty-six individuals. He remarks that clinical

evidence would indicate that the proportion was rather greater than this, being probably more nearly fifty per cent. than a little over thirty per cent., as these figures would indicate (B 1625).

As to the anatomical changes which syphilis of the brain produces in connection with the third nerve, Uhthoff found that out of thirty-seven cases in which post-mortem examinations had been made, the changes were as follows: In thirteen cases neuritis and perineuritis gummosa, with basal meningitis in six cases and no basal meningitis in seven cases; in thirteen cases direct lesions of the nerve trunk produced by specific new growths; in six cases complete destruction of the nerve tissue as the result of the invasion of the gummata; in four cases simple atrophy of the third nerve; in one case a gummatous condition of the muscle itself.

The specific changes in the trunk of the fourth nerve as the result of syphilis have apparently been observed in one case only (by Siemerling). In this instance the nerve trunk on the affected side was considerably atrophied.

Anatomical changes involving the sixth nerve were found by Uhthoff in twenty-six out of the one hundred and fifty cases. In ten of these twenty-six cases the paralysis had existed only on one side. The pathological conditions found were substantially the same as those which involved the third nerve, and in about the same proportion. Thus gumma is the most frequent change, occurring sometimes near the exit of this nerve from the brain and sometimes between that point and its exit from the skull. In only one case was there evidence of disease of the arteries.

The tissue of the muscles has also been found to undergo decided changes, either directly or indirectly, as the result of syphilis. Thus Siemerling found in some of "the paralyzed muscles the transverse striations had become indistinct or were entirely absent, having undergone a form of granular degeneration." It appears also that in many of these cases the entire muscle undergoes a form of atrophy, which results in a reduction of its size to even half of what it should be in the normal condition. The possible relation of this fact to heterophoria or heterotropia is evident, whether these changes

in the substance of the muscle itself are regarded as the direct effect of syphilis, or simply as a degeneration resulting indirectly from the paralysis of the nerve trunk or some of its fibers. This is one of the many problems to be solved in the borderland between ophthalmology and neurology.

(*b*) Diphtheria. This poison appears to affect primarily the anterior and central portion of the nucleus of the third nerve: ordinarily, therefore, it is manifested as an imperfection in the ability of the patient to accommodate. Such cases are exceedingly common and the literature of the subject is abundant. Usually after such a paralysis or paresis of the accommodation has existed for a few weeks or months, it gradually disappears as the poison is eliminated. Occasionally, instead of the muscles of accommodation, we find that the levator palpebræ or other muscles supplied by the third nerve are the only ones involved. The pathological process in the nerves themselves which results from a diphtheritic infection has been studied by Hochhaus (B 912) and others. In the examinations which he made in a number of cases, both of the nerves were paralyzed, and in a control observation of other nerves in the same subject not thus affected, he found that wherever such a paralysis or paresis existed there was a well marked inflammatory process in the tissue of the nerves. Although the branches which supply the muscles of accommodation are those usually affected by diphtheria, cases are not rare in which the sixth nerve is involved. Morton has reported four such cases, and although in three of these the accommodation also was affected, in one it was not. As diphtheria is so often a cause of insufficient accommodation, the bibliography of this subject is placed in that group of lesions (B 913).

(*c*) Tubercle. As the bacillus of tuberculosis may invade every portion of the body, it is not surprising that it should sometimes produce paralysis of the ocular muscles. Instances of this kind which have been reported by Parinaud and others leave no doubt of the fact. It is always difficult, though, to assert in any given case that this is the only cause of the paralysis.

(*d*) Malaria. This is another affection so widespread

that it is hazardous to assert that the paralysis is more than coincidence. Mannaberg has given an excellent summary of our knowledge of that phase of the subject (B 1687).

(*e*) Influenza. Although this disease does not ordinarily have any direct effect upon the deep nerve centers, yet occasionally, in the stage of general depression, symptoms of paralysis appear, especially of some branches of the third nerve. Such cases have not been infrequent of late years, although the association of the influenza and the paralyses may have been simply a coincidence, considering the large number of individuals who suffer from the former at certain seasons of the year (B 1609).

(*f*) Paralysis from other poisons. We are acquainted with several substances which, by their paralyzing influence upon other nerves, may also affect those which supply the muscles of the eye. Among them are alcohol and lead.

Slight temporary paralysis of one or more ocular muscles, with double vision and loss of co-ordination, is an ordinary effect of alcohol. In some cases this paralysis has become chronic (B 1632–1635).

Lead affects the system more gradually, and occasionally the nerves going to the eye, especially one or more branches of the third nerve. Usually, too, it is those branches which supply the extrinsic muscles (B 1636–1638).

(*D*) Ptomain poisoning. Acute paralysis of the nerves supplying the ocular muscles has resulted in a considerable number of well authenticated cases from eating certain meats, especially ham. Since Kerner, in the earlier part of the nineteenth century, called attention to the fact that some individuals were particularly susceptible to the poisons found in meats, especially in those which had been prepared by smoking instead of cooking, the literature has contained many of these cases. In a considerable proportion of them, fibers of the third nerve were particularly involved. More recently Groenouw reported five of these cases, with paralysis of the accommodation, and attention has also been called to the importance of the subject by Gutmann (B 1639). Those who may be interested in the subject will find an abundance of literature to show how frequent are cases of

this kind, especially in countries where the consumption of uncooked meats is common.

Einhorn, with other writers on diseases of the stomach, mentions the gastric idiosyncrasies of certain persons shown in the effect produced by special fruits, particularly strawberries, or by lobsters, crabs, oysters, etc.

(*E*) Ocular paralyses following diseases of the nervous system.

(*a*) Tabes. There is much diversity of opinion as to the frequency with which this produces ocular paralyses. Since my attention has been called to the relation between the eye and tabes, in the early stages the latter has been recognized in one or two cases where only the paralysis was noticeable before.

Gowers says in his *Diseases of the Nervous System*, "paralysis of the external ocular muscles is also common in tabes and occurs in several forms: [B 1643.]

"1. Transient weakness, lasting a few days or weeks, and then passing away.

"2. Permanent paralysis, complete or incomplete, of a single nerve or part of a nerve. Either form may occur at any stage, but the first is more common in the early and the second in the later stages of the disease." According to Swansey: "In the premonitory stages of tabes dorsalis, ephemeral, partial paralyses affecting now one, and again another of the orbital muscles, may sometimes be observed." (B 1654.)

The nerves which supply the ciliary muscles and the iris are also involved in tabes. In the very early stages there is usually contraction of the pupil, and when this occurs only on one side it is apt to be mistaken for dilatation of the other pupil.

The fourth and sixth nerves are also frequently affected in this disease, and in the very last stages we have occasionally a total paralysis of all the ocular muscles, both extrinsic and intrinsic (B 1644–1654).

The lateral motion of the globe in tabes is characteristic.

During the summer of 1902 I made photograms of the lateral movements of the eyes of several tabetic patients. These typical cases were selected from among many others,

by Dr. Hurd, Superintendent of the Buffalo State Hospital for the Insane, and kindly placed by him at my disposal. The results cannot be given in detail here. Indeed, several aspects of the question are still undetermined, but it is safe to say that in tabes, and apparently in a few other allied diseases, the usual motion of the globe is supplemented by a secondary one of a tremulous character. In certain cases this tremulous nature of the motion can be distinguished even without any instrument. But photography shows it to exist where it can not be recognized even by the most careful inspection. Thus photograms show the nature of this secondary motion and its degree. An illustration of this is given in Fig. 74. It will be seen that while the globe swings quickly

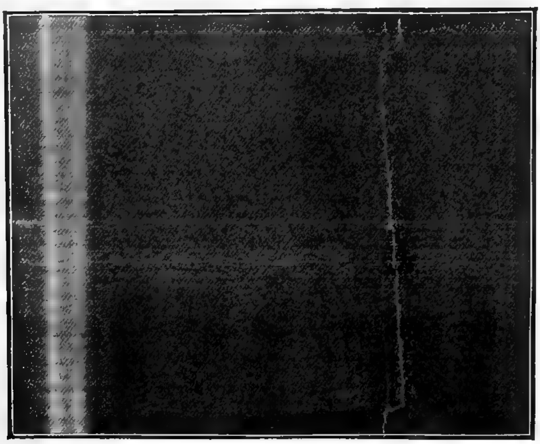

Fig. 74.—Photogram of the lateral movements in a case of tabes.

in one direction, then slowly backward, at the same time it makes short movements up and down. In the early stages of tabes these vertical oscillations can not be distinguished by the naked eye, nor by any other method, except as they are thus written on the photographic film. Apparently, therefore, we have in this a new and valuable means of recognizing tabes in the very early stage, when the ocular muscles are involved.

(*b*) Ocular paralyses occur also with Basedow's disease, syringomyelitis, Parkinson's disease, epilepsy, and several other morbid conditions of the nervous system. A discussion of them would necessitate too long a digression here; the reader who may be interested in the subject is referred to the bibliography (B 1655–1687).

(*F*) Paralysis as the result of accident. As we have seen that these various pathological changes may produce forms of ocular paralyses, so obviously most of these results may be caused by accident. These cases are extremely common and are of particular interest, for when post-mortem examination is possible we see just what brain lesions produce a given amount of paralysis of a given nerve (B 1688–1692).

It is evidently impossible here to consider all of the causes of paralysis of the ocular muscles, but the reader who is interested in the subject will find in the bibliography a sufficient number of references to start him, at least, in that line of inquiry.

CHAPTER VIII.

PROGNOSIS.

THE prognosis in paralysis of the ocular muscles depends upon an almost infinite variety of factors, which differ greatly from each other. The pathological condition which gives rise originally to the paralysis is of prime importance; though, no matter what that may be, much depends upon the age and recuperative power of the individual, and the length of time since the symptoms first appeared. As evidence of the extreme variations in the duration of these paralyses, an analysis of three hundred and twelve cases observed by Liebrecht may be cited, this number having remained under observation for a sufficient time to warrant some conclusions as to the prognosis. For purposes of comparison they were divided into four groups. (B 1693.)

First. Of twenty-one cases in which the cause was doubtful, nine recovered in from eight days to one and a half years, four were improved in from twelve days to two months, three with paralysis of the third nerve recovered with a dilated pupil, four were unimproved two years later, and one was unimproved after twelve years.

Second. Of six cases of pure specific origin, two were healed in four weeks, one in four weeks was improved, one in four months was much improved, one in six days showed perceptible improvement, one after five months was not improved.

Third. Of twenty-five cases which presented tabetic symptoms, eleven improved in from eight days to five months, five showed some improvement in from one to four months, nine in an interval ranging from two months to eight years.

Fourth. Of seven cases which presented other paralytic

symptoms, three recovered in from eleven days to five months, one improved, and three were unimproved after a term varying from seven months to one and a half years.

Such figures, however, give only a very general idea as to the prognosis in any case of paralysis.

CHAPTER IX.

TREATMENT.

The "practical" ophthalmologists may perhaps wonder that so much attention is given here to the symptomatology, the etiology, and the pathology of these paralyses, and so little now to their treatment. The local non-operative treatment, however, is not very satisfactory. Much has been written in regard to the use of electricity for these conditions, but the circumstances under which the interrupted or the constant current is indicated can be obtained much more in detail from any recent book on electrotherapeutics. In certain selected cases this treatment is of some avail. The muscles of the orbit, however, are so far beyond the reach of the ordinary electrodes, that this method fails frequently when it would be followed by good results in parts of the body which can be more easily reached. No matter what the character or strength of the current may be, the routine habit of applying it with a sponge or similar electrode simply in the vicinity of the affected muscle, is unscientific, unsatisfactory, and sometimes worse than useless. Whenever electricity is to be used, after deciding on the character of the current indicated in that case, an apparatus should be selected by which the strength of the current can be exactly measured, cocain should be applied, the eye rotated if necessary with the fixation forceps so as to bring the paralyzed muscle forward, and the electrode then applied directly over it. The best point for this purpose is flattened and blunt, about six or eight millimeters long by about half as wide. The current should not pass through the globe, if possible, and care should be taken, of course, by frequent examinations, not to have the applications too strong.

As for the general treatment, it is evidently impossible to

outline here what should be done for even a part of the various diseases which produce these ocular paralyses. The all-important fact is that the day of indiscriminate dosing has passed. Modern methods of examination, especially those furnished by bacteriology and chemical analysis, mean more definite diagnoses. That often means serum therapy with its various modifications, it means frequent measurements to ascertain whether our drugs are really producing the effects desired, and it means in general an accurate and careful therapy in place of slipshod guess-work.

A word, however, should also be added concerning the so-called heroic doses of potassic iodide and mercurials. As a considerable percentage of these paralyses are due to syphilitic infection, some practitioners begin in nearly every case with potassic iodide or mercurials or both, and continue them indefinitely in moderate doses. But gradually we have learned two things on this point. The first is that syphilis is by no means as frequent a cause as older writers supposed; and, second, that if potassic iodide or mercurials are to be given at all, the doses should be gradually increased until the constitutional effects are produced. The amounts sometimes necessary for this are surprising. The uncomfortable symptoms experienced by the patient, or the occasional blame for the attendant for producing them, are of little importance compared with what then is at stake in the lasting benefit of the patient.

SUMMARY OF PART III.

As the plan pursued in the study of the paralytic deviations is a familiar one, it is only necessary to recall the outline suggested at the beginning. That is, the ocular paralyses have been treated as a whole. The symptoms and causes were studied together, except as these varied in the paralyses of certain nerves or branches of a nerve. As the non-operative treatment depends principally upon the removal of the cause, and as it is evidently beyond the limits of this volume to consider the treatment of the different diseases which produce ocular paralyses, the reference to treatment was necessarily very brief.

PART IV.

ATYPICAL MOVEMENTS OF THE EYE. INFLAMMATIONS AND INJURIES OF THE MUSCLES.

CHAPTER I.

ATYPICAL MOVEMENTS.

DIVISION I.

ATYPICAL MOVEMENTS—NOT PROPERLY NYSTAGMIC.

§ 1. **Definition**—These are movements of the eyes which do not seem to be related in any way to the deviations which we have considered. We avoid confusion therefore by placing them together in a separate group.

§ 2. **Voluntary Movements of One Eye.**—Occasional instances are described of persons having apparently the curious ability of moving one eye quite independently of the other. It is doubtful, however, if that ever occurs; more careful examination shows a paralysis in one eye, while the other moves normally (B 1701–1707).

§ 3. **Retraction Movements of the Eyes.**—These cases are rare, but still appear in the literature every few years with a certain degree of regularity. Ordinarily the ability to draw the eye within the socket is only such as to attract attention on rather close scrutiny, but occasionally we find one in which this peculiarity is very marked. No dissections have been made to determine whether or not the extrinsic muscles in these individuals differ in position or size from those in the ordinary orbit. But, when making a tenotomy

in such a case Knapp found "the tendon very thick and its insertion line reached downward almost to the insertion of the inferior rectus." This, and similar facts indicate that the power of retraction is dependent upon an unusual development of the recti, or the presence of additional muscle fibers in the orbit. (B 1708–1715.)

§ 4. **Atypical Associated Muscle Action.**—These cases occur so frequently that they may be classed among the rather common atypical movements. They consist in the synchronous contraction of the ocular muscles with muscles of the face or of the upper part of the body. Quite often the act of chewing is accompanied by a corresponding motion of the lid. A considerable number of such cases are found in the literature (B 1716–1731). Occasionally the associated movement is that of the tongue with the lid (B 1725), or there may be an associated movement of the entire head with the nystagmic movements of the globe (B 1519–1522). Thus far no one has observed a sufficient number of these cases or sufficiently classified those which have been reported, to formulate conclusions as to causes. Therefore we can simply call them cases of associated muscular action and regard them as pathological curiosities (B 1716-1731).

§ 5. **Hysterical Deviations.**—These should be mentioned for the sake of completeness. Cases have appeared in the literature from time to time in which the deviation is apparently a direct cause of hysteria, and prominence is also given to the supposed connection between these two conditions. But when we study them carefully, they fall into some one of the different categories which have been mentioned already, as we find also either a hypermetropia, some imperfection of the power of perception or of the refractive media. It is true that in these persons the element of irregular muscular contraction, such as occurs with unusual excitement, is an important factor, but this is only a different degree of what we find in many cases of periodic deviations.

CHAPTER I.

DIVISION II.

NYSTAGMUS.

§ 1. **Definition and Varieties.**—Under this term are included all irregular or jerky motions of the eyes, no matter what may be their direction, extent, or duration. The various forms of nystagmus not only differ essentially from each other, but are dependent upon different causes. Indeed, this general term, "nystagmus," undoubtedly includes at least two or three distinct pathological conditions. Thus we have:

(*a*) *Nystagmus horizontalis*, the most usual form, involving the lateral muscles. In this, the eyes together make a jerking motion in one direction, perhaps to the extreme limit of the field of fixation, and then a similar motion in the opposite direction, nearly or entirely to that limit of the field. Or we have:

(*b*) *Nystagmus verticalis*, involving the supra- and subductors (very rare), or:

(*c*) *Nystagmus rotatorius*. This may consist in a rotation of the globe about the antero-posterior diameter, both eyes turning in the same direction at the same time, or, in exceptional instances, the upper end of the vertical axes may turn in opposite directions. The variations in the degree of nystagmus are quite as great as is the character of the motion. Sometimes the peculiarity is so slight as not to attract attention, being apparent only when the patient is under unusual excitement. In others the motion is constant and the globe swings through a considerable arc.

§ 2. **The symptoms** are:

1st. The jerking and unnatural movements just mentioned.

The photogram in Fig. 75 was of a man whose slight nystagmus was apparent only on rather close examination. At A we notice the beginning of a swing outward, but there

was a halt before it reached the point B. There the halt was very short before it started to swing inward, and in doing so it halted at C before reaching the extreme limit at D. The rest was comparatively long to E, and that swing outward was short and uninterrupted to F.

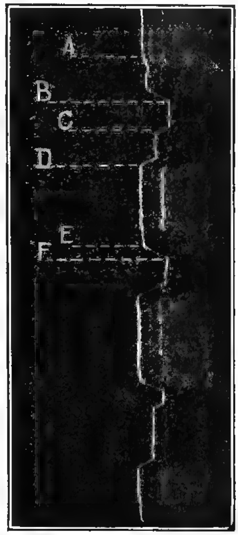

FIG. 75.—Photogram in a case of nystagmus. This shows considerable freedom, but great irregularity in the motion of the globe.

The essential point is that the irregularity of the motion of the globe was greater than it seemed.

2d. The position of the head. In certain cases this is very peculiar. Sometimes the head turns in one direction, sometimes in another, or the patient may be obliged to turn the object looked at in a particular position if he wishes to see it to the best advantage.

3d. Vertigo. This is found only in the earlier stages, and before the nystagmus is well established. Later the jerking or rotary motion of the eyes persists, but the person is unconscious of it; the dizziness has disappeared, but usually the vision is imperfect.

§ 3. **The causes** have been the subject of speculation rather than of careful study. It is convenient to divide them as usual into two classes, the remote and immediate. Formerly it was supposed that nystagmus was always congenital and entirely incurable, but of late our views on both these points have been somewhat modified.

I. Among the remote causes are:

(*A*) A central nerve lesion such as has been frequently noticed. In these cases there is also occasionally present some lesion of the auditory nerve. Again we have:

(*B*) Nystagmus dependent upon some congenital or acquired error of refraction. The more we study these cases, the more interesting does the subject become and the more

satisfactory are the methods of treatment. A very striking example of this is reported by Crzellitzer (B 1785) of a patient eleven years old in whom nystagmus of a high degree was associated with zonular cataract. After iridectomy, extraction of the cataract, and proper correction of the refraction, the nystagmus disappeared entirely.

(*C*) Changes in the fundus, especially retinitis pigmentosa, albinism, and certain forms of amblyopia are also frequent causes of nystagmus. Such causes, existing either in the central nervous system or in the eye itself, produce the greater part of what we class as congenital nystagmus.

II. Among the immediate causes are:

(*A*) Imperfect muscle action through disturbance of the general system. An interesting case of this kind is reported by Malone (B 1756).

A woman of thirty-five, previously in good health, developed about the fifth month of her ninth pregnancy a well-marked nystagmus. This was not only apparent objectively, but, as she said, objects appeared to "dance up and down," producing a sensation of dizziness. The vision of both eyes, however, remained practically normal. This condition continued for a year or more following the pregnancy.

(*B*) Again, nystagmus may be produced by a persistent and extreme tension on certain groups of the ocular muscles.

Javal long ago observed that if both eyes are turned to the extreme limit of the field, to one side or the other, and held in a state of unnatural tension persistently for a considerable time, when they resume a natural position there occurs sometimes a sense of discomfort and an apparent oscillation of objects looked at.

It is also interesting to note that a form of nystagmus can be produced artificially in rabbits. This has been done by removing a part of the hemisphere, and after the animal has recovered, placing it on a stand and revolving it a few times rapidly in one direction. The eyes then show very distinct nystagmic movements for several minutes. These have been considered "compensatory" movements, though their character is not yet well understood.

Nystagmus of Miners.—This constitutes almost a special disease. It does not develop among all classes of workmen, but only among those who are obliged to use the pick, especially in mines not lighted by electricity. When the light consists simply of a small lamp attached to the head of the miner, and he is obliged to assume unusual positions, sometimes lying on his back while using the pick, the eyes must be turned into constrained positions and held fixed in that manner for a considerable time. Under such circumstances a nystagmus is apt to develop. In the early stage the symptoms are often absent entirely for weeks or months, especially if work is interrupted. At first the patient may experience discomfort or dizziness. Later these subjective symptoms disappear, but the jerking movement of the eyes has become fixed. In a word, the evidence is such as to leave no question but that the acquired nystagmus is the result of the occupation (B 1760–1768).

§ 4. **Treatment.**—Naturally we ask first what can be done by way of prevention. Not much, it is true; still something can be accomplished for the nystagmus of miners, if the patient will abandon his work for a time when the disease first appears. These people are usually too ignorant and careless to be much influenced by advice. But it is probable the time is not far distant when the surgeons employed by the coal companies will recommend that such patients be given another form of occupation or discharged.

Next to prevention, non-operative treatment suggests itself. As there is ametropia in so large a percentage of these cases, its correction with glasses is of course indicated. But this cannot be done in any hasty and off-hand manner, and even with the utmost patience and care, improvement is possible in only a small proportion of cases. Still it is also true that we have been too much inclined until recently to be discouraged just because these patients are "born so." It should be noted that the possibility of improvement from glasses is proved by a considerable number of cases now on record.

Finally, it may be asked what improvement, if any, can be expected from operation. Many attempts of this kind have

been made, but usually with disappointing results. It is probable that most of these tenotomies were done in rather a haphazard fashion, and without a very definite conception as to which muscle or group of muscles was particularly affected. All that we can say at present is that the evidence thus far at our command is not such as to warrant the expectation of improvement from such interference. The entire subject is one which offers a promising field for re-arranging the few data we have, and for supplying some of the many which we lack.

CHAPTER II.

INFLAMMATIONS AND INJURIES OF THE MUSCLES.

§ 1. **Rheumatism.**—As the condition which we call rheumatism frequently affects other muscles and also the iris, it is not strange that it should occasionally invade the extraocular muscles. Rheumatic iritis is dealt with in the text-books much more in detail than is possible here (B 1794–1795).

§ 2. **Myositis.**—A distinct inflammation of the extraocular muscles is of course an exceedingly rare condition, but a few cases have fallen into the hands of careful observers, and in one instance, an opportunity was afforded for microscopic examination of the condition. That was a case reported by Gleason. The patient, a man past middle life, complained of pain in one eye when it was rotated, swelling of the conjunctiva with marked exophthalmus followed, then corneal ulceration, and afterwards enucleation became necessary. Examination showed no cellulitis of the orbital tissue, but the superior rectus was found to be "enormously enlarged, immovable, and hard as a board." Microscopic section of this showed interstitial myositis.

About a month later the patient returned with similar symptoms in the other eye, purulent keratitis followed, and enucleation of the second eye was made. On this side "all of the extraocular muscles were increased in size, and felt as hard cord-like bands." The patient was subject to rheumatism, and suffered from quite a severe attack simultaneously with the myositis in each eye (B 1791).

Other observers have met with cases of inflammation of the ocular muscles, but usually there has been a question whether an orbital cellulitis may not also have been a prominent element in the case.

§ 3. **Progressive atrophy** of the ocular muscles has been observed, and although these cases are rare they have not received the attention which they deserve. Naturally, only the most pronounced cases attract attention clinically. In as much as a certain amount of weakness of muscles occurs in the other portions of the body, without passing into the condition which we call atrophy, there is every reason to conclude that a similar weakened condition of the ocular muscles occurs even more frequently than is usually supposed. The relation of these conditions to forms of heterophoria and heterotropia suggests an interesting question for investigation (B 1789).

§ 4. **Injuries of the Extraocular Muscles.**—In this group we shall consider only accidental injuries, although with propriety we might include some results of operations. Accidents of this nature are rather more frequent than might at first be expected. The rather interesting point concerning them is the amount of laceration which the extraocular muscles can undergo without damage to the globe, and sometimes with comparatively little interference with the motility (B 1796–1800).

As an illustration of the amount of injury which a muscle can sustain, mention may be made of quite a striking case which was sent to me. A young fellow eighteen years old, who weighed about a hundred and twenty or thirty pounds, jumped from a sleigh directly against one of the projecting iron cranes on which butchers are accustomed to hang quarters of beef. The point of the hook, which fortunately was blunt, entered the orbit, passed under or through the internal rectus, and rested against the upper wall of the orbit. He hung in that position until he was lifted off. Severe symptoms of compression followed, among them vomiting and delirium, but after a considerable illness he recovered. When he came for examination the globe on that side was practically normal, although there was extreme divergence. Closer examination showed the line of the wound, and that the internal rectus was set far back or absent entirely, but in spite of that the eye could be rotated inward quite perceptibly. This was accomplished, of course, more by the superior and inferior

rectus than by any portions of the internal rectus which could have remained after so severe an accident. The vision of the eye was reduced to perception of light.

Such cases of injuries of the extraocular muscles are interesting rather because of their unusual character, and are to a great extent ophthalmological curiosities.

PART V.

OPERATIONS ON THE MUSCLES.

CHAPTER I.

GENERAL CONSIDERATIONS.

§ 1. **Evolution** of tenotomy. A better idea can be gained of operations on the recti by first glancing at their development with regard to two points. One is the reason which prompted the making of any operation at all, and the other the improvement in the technique.

The object at first was merely to overcome a deformity. Some accounts indicate that the idea of an operation to accomplish that originated some sixty or seventy years ago with an Englishman named Taylor. He was a clever rascal of itinerant habits, with some knowledge of medicine and a much larger fund of assurance, who insisted through many pages that he cured squint. We do not know exactly what he did, nor how he did it. Indeed, some deny that Taylor cut the rectus muscle at all, but from his abundant writings it appears that he made an operation with that in view whenever an opportunity offered, and it is possible that occasionally, and perhaps accidentally, he did divide that muscle. If the eyes of his patients did often "turn the wrong way," that is a fault to which many of to-day must needs be charitable. (B 1801.)

In 1838, an orthopedic surgeon, Stromeyer, published an account of a myotomy or tenotomy made on the cadaver, and the next year Dieffenbach, then Professor of

Surgery in Berlin, recorded the first division of the internal rectus in the human subject (B 1802–1803).

This very short but also very important article is as follows:

"I have obtained a perfect result in a case of convergent strabismus in which I divided the internal rectus muscle. Professor Jeenken, who witnessed the operation, was also much delighted by the result. The patient was a boy of seven. The eye was drawn far inward and the consequent deformity was very decided. I made the operation as follows: The head of the child was leaned against the chest of one assistant, another assistant drew the upper lid upward with one hook and the lower lid downward with another hook, so that the palpebral fissure was as wide as possible. Thereupon I pushed a third hook through the conjunctiva at the inner angle of the eye and quite through the deep cellular tissue there, and that hook I gave to a third assistant. Then I stuck a fine little double hook into the sclerotic at the inner angle of the eye, and holding it in the left hand, drew the globe as far outward as possible. I incised the conjunctiva, close to the globe where it is spread out at the inner angle of the eye. Going deeper I dissected the cellular tissue from the ball, and then divided the muscle with a pair of fine eye scissors close to the globe. Thereupon the latter, being drawn upon by the external rectus muscle, turned outward quick as a flash and immediately became straight, so that no difference could be detected in the position of the two eyes. The hemorrhage, although quite abundant, was not sufficient to interfere with the operation. The after-treatment consisted in cold applications. There was no subsequent inflammation of the eye, and within eight days the healing was complete. I am particularly indebted to Dr. Boehm for special care given to the child after the operation. In Stromeyer's excellent monograph on subcutaneous orthopedy, he mentions having made investigations as to the possibility of dividing the internal rectus for the cure of squint, but thus far it has not been done on the living subject. It is to be hoped that this may find an established place in Ophthalmology."—Dieffenbach.

From this and all the other earlier literature, it is evident that the first attempts to straighten the eyes were by myotomies as much as by tenotomies. Naturally the eye often

"turned the wrong way," and very early in the literature we find accounts of some form of advancement. These will be considered later. Confining our attention to operations for lessening the action of a muscle, we find that for more than ten years after Dieffenbach, operators seemed neither to know nor to care much whether they cut the muscle or its tendon. Certainly they did not trouble themselves about secondary insertions. That may be called the first period in the evolution of these operations.

The second period includes that in which myotomies were discarded and total tenotomies were made, but without any special care in the division of the secondary insertions, and therefore with comparatively little regard to the correction desired. Quite a number of these methods of dividing the tendon have been described. Some of them, more or less modified, are still in constant use, and therefore should be described here at least briefly. They are as follows:

(A) von Graefe's method. Although not the first tenotomy proposed, it has probably been followed in one form or another by the greatest number of operators. After introducing the speculum, the surgeon seized a fold of the conjunctiva in a direction tangent to the cornea and five or six millimeters from its internal edge. The conjunctiva was divided, the point of the hook was pressed firmly against the sclerotic below and behind the insertion of the tendon, and that being fully exposed, was then divided. In order to make sure that no fibers remained, the hook was passed up and down, to catch these and separate them also, although that was not done if only a slight effect was desired (B 1807).

(B) Liebreich divided the conjunctiva across the fibers of the muscles just over its insertion, and dissected the conjunctiva and the anterior secondary insertions free from the muscles as far as the caruncle. Then he practically cleared the muscles and tendon entirely of secondary attachments and divided the tendon. The conjunctival wound was closed with a suture (B 1809).

(C) Critchett made an opening in the conjunctiva near the lower edge of the tendon, wide enough to admit the large strabismus hook. Through this opening the hook was passed

upwards, and the tendon lifted on it. The scissors were inserted through the same opening and the tendon freely divided. This was called the subconjunctival operation (B 1806).

These are only a few of the various methods which have been described for dividing the tendon. The instruments used were large and clumsy, and although they are still seen, it is difficult if not impossible to do accurate work with them. The point is that in practically all of these tenotomies the single object seemed to be to divide the *entire* tendon, and to do so without much regard to the delicate connective-tissue bands which constitute the secondary insertions. This was the second period.

The third and final period may be called that of exact tenotomy. In this the operators take into account not only the primary but the secondary insertions. The instruments are small, the dissection is made accurately, and care is taken to have the number and the position of the fibers which are divided, correspond more accurately to the effect desired. The beginning of this period, as usual in evolution, is not clearly defined. Early in the seventies more delicate scissors and hooks began to be used, and greater care was taken in the dissection. Especially was this marked after the discovery of cocaine. It is probable that Stevens called attention more than any one else to the necessity of exactness. The fact is that all of the more careful operators, when making tenotomy for correction of deviations, now use the hook and scissors, which are much more delicate than formerly, although the older instruments are better for the tenotomies of enucleation and for most forms of advancement. Moreover, we are learning constantly to take more care in the diagnosis which determines how much of a correction is desired, and to give still more care to dividing the corresponding fibers of the tendon and those fibers only.

A summary of the evolution of tenotomy would be incomplete, however, without reference to the development of our views as to the *object* to be attained by both tenotomy and advancement. It was soon learned that when the deformity was corrected at an early stage, while binocular vision

still existed, not only was a better result obtained, but there was less danger of the eye turning from the position in which it was thus artificially placed. That idea of the *importance of binocular vision*, which we owe largely to Donders's work on refraction, developed gradually. It has been discussed by many ophthalmologists, but by none perhaps more clearly and forcibly than by Javal and Landolt. This later idea of the object of tenotomy, meant not simply operation, but also the use of glasses sometimes before the operation and usually after it. With this glance at operations on the ocular muscles—especially tenotomy—we are better prepared for a few general considerations which apply both to tenotomy and to advancement, before studying either of these operations in detail.

§. 2. **Position** of the patient.—If general anæsthesia can be avoided and if binocular vision can be elicited, it is better for the patient to sit than to lie down. This is contrary to the usual teaching, but one of the advantages of the sitting posture is, that the patient is not alarmed by the paraphernalia of the table. Many a child will sit in a chair and allow his attention to be engrossed by tales of playthings or of pets, who has not the least interest in such matters when he is stretched out on a table.

The second and by all odds the greatest advantage of the chair over the table is that if the test light is immediately in front, there is no necessity of having the patient arise every few minutes in order to make the tests during the operation. We have only to remove the speculum, wipe the eye, put on the frames which contain the prisms or the Maddox-rod, and in a moment we have the result.

The chair suggested long ago by Knapp (Fig. 76) holds its place, and is altogether one of the simplest and best. As for the table, any will do which can be made surgically clean. One model lately proposed by Hess affords an opportunity to change easily the position of the patient. It is nothing more than an operating table top, adapted to the base of a pneumatic chair, such as is used by barbers and dentists. This can be pumped up or down or revolved this way or that as desired.

But whether a table or chair is used it is essential to keep the hands of the patient from flying up to strike the hands of the operator. When the patient sits, the hands can be watched by an assistant and held if necessary. If a general anæsthetic is necessary, the hands of the patient and his body also should be strapped to the table. Hardly any spectacle is more unworthy of the dignified quiet which should pervade an operating room, than to see orderlies and nurses struggling with a patient when all of the confusion can be avoided by a few strong straps which keep the patient just where he belongs.

FIG. 76.—Knapp's operating chair.

§ 3. **Aseptic precautions** for tenotomy or advancement. These operations are not dangerous to the globe, but with aseptic and antiseptic methods we gain in two important particulars.

First. The healing is rapid, being without suppuration or granulation, and

Second. The resulting scar is reduced to the minimum.

These are sufficient reasons for aseptic precautions, and the fact that they are so often neglected is the apology for mentioning them here. Among these are:

First. Cleanliness of the hands of the operator. He should not be satisfied with merely washing them, but should scrub the fingers well with soap and water and clean out thoroughly

the spaces beneath the nails. After this it is advisable to soak the hands in a solution of sublimate, 1 to 1000, for at least a minute or two. It would seem unnecessary to add, that the hands should then be kept thoroughly clean. Yet how often do we see a surgeon exercise the utmost care in disinfecting his fingers, and forthwith thrust his hand into his pocket to search for a handkerchief, or forget himself in some similar fashion !

Second. Cleanliness of the conjunctiva. Many operators are content to bathe the eye before operation with a solution of sublimate, but that is seldom sufficient if we wish the best result. For, if the lids are turned and the whole conjunctiva well flushed, we can often succeed in washing out flocculent masses of secretion. In a word, it is worth while to disinfect the conjunctiva as thoroughly as if we were about to make an iridectomy or remove a cataract. One of the simplest and best means for doing this is with a wash-bottle.

Several of these flasks have been placed on the market, and after trying different models I had one arranged such as is seen in Fig. 77. This has the advantage that the air which

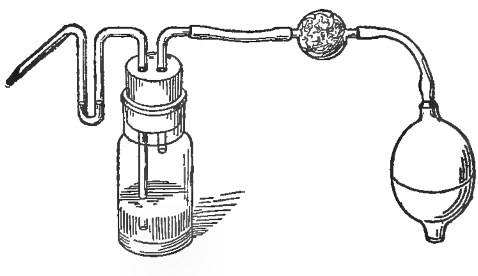

FIG. 77.—Wash-bottle of the author.

enters the bottle is at least partly filtered by passing through absorbent cotton, and by keeping a few drops of this solution in the bent tube of exit, the solution in the flask is protected somewhat from contamination.

Third. Disinfection of instruments. Of all the plans which have been proposed for cleaning instruments, the culture tube indicates that soap, brush and boiling water, if

properly used, are about as good for the instruments and as bad for the bacteria as any method at our command, except, of course, steam sterilizing. Under any circumstances the nurse should have a magnifying glass with which to examine each instrument, in order to be sure that it not only looks clean but is clean. Too often the disinfection is only a perfunctory rite. Even when instruments, forceps especially, are in constant use, as in a hospital, minute spots of rust are apt to appear upon them, and form excellent depots for the bacteria which patients exchange with each other under the guidance of the surgeon.

§ 4. **Anæsthesia.**—General anæsthesia is to be avoided if possible. It is unnecessary, except under unusual circumstances, or when dealing with very young children. It is true, neurotic or spoiled children of any age will insist that they are "too nervous" to have any operation made without chloroform or ether, but if such people are dealt with patiently but firmly, and above all truthfully, as to the real discomfort, they will usually permit even painful operations to be done with local anæsthesia only, and afterward be thankful for the escape from the nausea.

In rather exceptional cases of operations on the muscles, especially for advancement, general anæsthesia does become necessary, but if a local anæsthetic be also used first, a small amount of ether or chloroform will suffice.

§ 5. **Adrenalin Solution.**—Next to local anæsthetics, one of our most valuable drugs is the extract of the suprarenal capsule, either in the form adrenalin or some one of the other preparations of the class. As the technique of tenotomy or advancement in any one of their various forms becomes more perfect, we find, of course, that each step can be taken with greater accuracy when the field of operation is free from blood.

§ 6. **Magnifying Glasses.**—Modern operations on the muscles are often dissections such as are made under a microscope. Therefore magnifying glasses of some kind are always convenient and sometimes necessary. When the eyes of the surgeon are practically normal, with the exception of some presbyopia, a pair of strong magnifying glasses

set in suitable frames are quite sufficient. Many operators are accustomed to use such spectacles when operating for cataract, but some tenotomies, if properly made, are procedures quite as exact.

The binocular loupe of Jackson is stronger than the magnifying glasses. Some operators prefer the loupe which has been recently devised by Hess, which consists practically of the lenses attached to a projecting rod held by a head band. Each surgeon has his own preference as to what the magnifier shall be, but when dissection is to be made of microscopic objects, some method of magnifying is evidently essential.

§ 7. **The personal equation** of patient and surgeon. We all know how much the good behavior of a child can assist the surgeon in an operation on the muscles, and how another child, with the same condition, can make a good result difficult or impossible. It is therefore worth while to teach a patient how to behave during the operation, otherwise the novelty of the situation may frighten him into the loss of what little self-control he might otherwise have. This education consists in first assuring him that no cutting would be done at that sitting, then to apply cocain, insert the speculum, and pinching up the conjunctiva together with the muscle, turn the eye from one side to the other. If diplopia is produced by prisms and the tests are also made with them, the patient, especially if a child, learns how to give intelligent replies, as he certainly would not if the same questions were asked while he is under the excitement and suffering the discomfort of the real operation. This plan of accustoming the patient to the routine of an operation has long been used in some clinics as part of the preparation of patients with cataract.

As for the surgeon himself, he should have an instinctive knack in dealing with little mechanical details, but he must also have acquired in some way what we call dexterity. Some men are ambidextrous, others ambisinistrous: for the former, only a hint as to the technique of an operation is necessary; for the latter, not even the most careful description avails. It is one thing to tell a boy how to hit a ball with a bat, but it is another thing for him to do it.

§ 8. **Precision** in operations on the recti. Unfortunately we are still far from attaining that precision in operations on the muscles at which we aim. Let us therefore glance at a few of the factors which enter into the problem. These are:

(*A*) The amount of the deviation.

(*a*) We should know as nearly as possible what the amount of the deviation is and also have our record of it as complete as possible. After all that has been said in regard to the different methods of measuring the deviation, it is only necessary to refer to them here. The point to which attention is now particularly directed is the advisability of recording the amount of the deviation not only in figures but by the graphic representation already described.

(*b*) We should also remember that, other things being equal, a certain definite change in the insertion of a rectus muscle means a corresponding change in the position of the visual axis. Thus, if we describe a circle with a radius of about eleven and a half millimeters (the size of the normal eye), then a chord or a tangent one millimeter in length corresponds to an arc of about five degrees. (Fig. 78.) For so small an arc, the chord and tangent can be considered practically the same. On the large myopic eye a change of one millimeter in the position of the muscle makes a corresponding lesser change in the position of the visual axis, while in the smaller hypermetropic eye one millimeter makes a greater change.

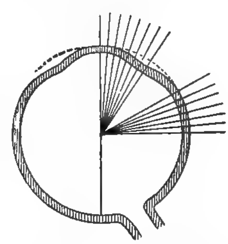

FIG. 78.—A change of one millimeter in the insertion of a rectus corresponds to a change of about five degrees in the position of the visual axis.

It is true that ordinarily other factors must be taken into account, such as the strength (the lifting power) of the adductors or of other muscles, the degree of hypermetropia present, etc. But apart from these other matters the fact remains that for practical purposes each millimeter counts for about five degrees.

This is important and its clinical bearing has apparently escaped observation. It forms the basis of our estimates

of the position of the globe no matter what operation is undertaken.

We should remember, however, that the traction to rotate the globe is exerted by any muscle from its origin to the point of its contact with the globe—except when the muscle passes through a pulley.

(*B*) The second element which enters into this question is the strength exerted by the muscle or group of muscles toward which the visual axis deviates.

(*C*) A third element is the force exerted by the muscle away from which the visual axis deviates.

(*D*) A fourth part of every such problem is to estimate as well as possible, before operation, what traction force will be exerted ultimately by a muscle after a proposed tenotomy or advancement or with both operations on the same eye.

§ 9. **Classification of Operations on the Recti.**—Two opposite effects are sought for by these operations; one is to lengthen a muscle, the other to shorten it. To state this principle more in detail, if we wish:

(*A*) To lessen the action of the recti in the minimum degree, we divide a part of the primary insertion. That is partial tenotomy.

(*B*) To lessen the action of the muscle to a greater extent, a division is made of all of the primary insertion. That is central tenotomy or simple tenotomy.

(*C*) To arrest the action of a muscle entirely, a division is made of both the primary and all the secondary insertions. This is total tenotomy. The effect of a tenotomy can often be increased at least temporarily, by stretching the muscle before dividing the tendon.

The action of a muscle may be increased by the opposite method.

(*A*) To increase the action of one of the recti in the minimum degree, we shorten it slightly by "folding" or "tucking" the tendon.

(*B*) To increase its action to a greater degree, we divide the tendon and re-attach it nearer the cornea (true advancement).

(*C*) To increase its action to the maximum degree, we

divide the tendon, excise its extremity, and re-attach the muscle at a point nearer the cornea (advancement with resection). The effect of an advancement is increased by tenotomy of the opposing muscle and that is usually done.

It is probable that these subdivisions of the operations may seem to some readers unnecessary or practically impossible. In most text-books we find descriptions of "tenotomy" and "advancement," and some writers separate "tenotomy" from "free tenotomy," whatever that may be, and those operations from tenotomy with displacement backward. But if we are to bring any order out of this confusion of ideas concerning operations on the muscles we must do two things: first, keep clearly in mind the anatomy of the parts involved, and know just what fibers are divided in any given operation; and second, decide upon terms which shall describe each operation briefly and accurately in order that our own records may be definite and our reports based upon them intelligible to others. In the first volume much space was given to the discussion of methods of dissecting these muscles and to an examination of the manner in which they were attached to the globe by their primary and secondary insertions. The object of that was to obtain an anatomical foundation for surgical work. No one can appreciate the importance of these fibers nor the rôle which they play in different procedures, who is not thoroughly familiar with the filaments of connective tissue which make up what we call "the insertions." They should be studied in photographs of some sort, or still better by dissections, and the more firmly such an anatomical foundation is laid, the easier will it be to understand the reason for separating these various operations from each other and to execute them satisfactorily.

CHAPTER II.

TENOTOMY.

DIVISION I.

PARTIAL TENOTOMY.

§ 1. **Definition.**—Partial tenotomy consists in the division of part of the fibers of the primary insertion. A part or all of the fibers of the secondary insertions may also be divided, according to the amount of correction desired.

Partial tenotomy has also been called "graduated tenotomy." That simply means that the amount of the correction is gradually increased in successive stages at the same sitting or at different sittings. Every tenotomy and every advancement also ought to be "graduated" to suit the demands of the special case.

§ 2. **Is Partial Tenotomy Possible?**—This question is raised because it has been asked seriously by those whose clinical experience should teach them better. Any good dissection will show how simple it is to divide part of the fibers of an insertion. Probably every operator has thus divided only a part of the fibers of a tendon, and on removing the speculum and cleaning the eye, found that the deviation was apparently just as great as before. In other words, a partial tenotomy had been made—unwittingly, it is true, and usually not in the most exact manner—but still a partial tenotomy. If the division were sufficient, more exact tests would have shown some change in the position of the globe.

§ 3. **Indications** for partial tenotomy. Some practitioners may think this should never be done. Many of our foreign confrères will continue to regard the idea simply as a "Yankee notion" comparable with wooden nutmegs. It is also true

that extravagant claims of wonderful results have furnished reasons for that view. But any one who considers the facts candidly must admit that, during the last decade especially, conservative judgment has crystallized into a favorable opinion concerning operations which carefully and exactly lengthen the tendon in only a slight degree. As the indications for partial tenotomy and slight advancement are in certain cases practically the same, they can be considered together. The question which one should be done with a given condition will be taken up later. One or the other is indicated:

First. For a heterotropia of a slight degree. Cases come to us constantly with esotropia in such a slight degree that we hesitate to make the usual forms of tenotomy. Some have already had an operation made but a little deviation still remains. This is often just enough to constitute a deformity, to give rise to diplopia, or to interfere with efforts to establish binocular vision.

Second. Partial tenotomy or slight advancement is sometimes indicated for certain forms of heterophoria accompanied by severe asthenopic symptoms. It is these cases, when improperly selected, which have discredited such operations; but it is also these, when carefully chosen, which give the most satisfactory results. The following propositions seem to formulate fairly well the present state of ophthalmological opinion, in this country at least, concerning these operations for heterophoria.

(*A*) No operation is ordinarily warrantable until all other methods of treatment have proved unavailing. This refers not simply to the exact correction of ametropia or the use of prisms and other means for local treatment, but it means also that every effort should first be made to bring the general condition of the patient to a standard of perfect health.

(*B*) Operative treatment is very seldom indicated for any form of esophoria.

(*C*) It is sometimes indicated for exophoria or hypophoria. When this is a passive exophoria, some form of advancement, as we shall see, is preferable to tenotomy. When no other treatment for imbalance gives relief, the question is simply whether we shall allow a patient to drag out a more or

less miserable existence, perhaps struggling to earn a living, or shall we at least give him the benefit of the doubt by a procedure which is perfectly safe ? To this apparently there is but one answer.

(*D*) Economy of time may sometimes constitute a reason for operative interference. Some private patients are fortunately so situated that there is ample time to persist in prism exercises or some other slow plan of treatment. That course is usually preferred by the patient and more creditable to the surgeon. For at the slightest hint of operation many a patient takes wing to be seen no more. But if we have to deal, for example, with a bookkeeper who can ill afford the time and expense necessary for such a long routine, or with some patient who lives at a distance and must soon return home, what is to be done? These different factors must be weighed. The question is sometimes embarrassing, but none the less very practical, and while the presumption is of course always against operation, the reasons sometimes turn the decision in favor of it.

§ 4. **Methods of Making Partial Tenotomy.**—This was practised by von Graefe, and it is probable that he and others made what we now call central partial tenotomy (B 1810). But when we consider how crude were the instruments and the methods of using them, it is not surprising that the results were disappointing.

Von Graefe's idea, however, was not forgotten, and during the early seventies Noyes and other operators were graduating the effects produced by tenotomies. A little later Stevens also used the more delicate hook and scissors, and attention was called to them and to partial tenotomy rather because of the unusual claims of benefits derived from it. (B 1838–1839, p. 135.) He made a form of what we shall consider later as central partial tenotomy (B 1839, p. 204).

In a somewhat similar manner he also made a lateral partial tenotomy in Fig. 79. But this figure seems to show rather how that form of partial tenotomy should not be done, the line of the incision in the tendon being unnecessarily oblique.

Quite recently Verhoeff (B 1849) suggested a "graduated

plastic tenotomy," its object being to produce a slight retraction of the muscle without complete division of it. The method is as follows: an incision is first made in the conjunctiva and the superficial tissue, so that the tendon is laid bare for some distance and its fibers well isolated. The muscle is then caught up with the forceps and cut almost entirely across at its center a few millimeters from the insertion (C, Fig. 80). Two short nicks (AA′) are made on one edge of the tendon and two other nicks (BB′) opposite the first pair. This leaves a small narrow band of fibers in the center of the principal insertion. When the parts are stretched, the buttonhole assumes an oval form, thus practically lengthening the tendon. Verhoeff reports that in this way he has obtained a correction equal to about ten degrees. Although the procedure appears simple enough in the diagram, it was found rather difficult to make this "nicking" in the muscle accurately, especially at the points more remote from the insertions.

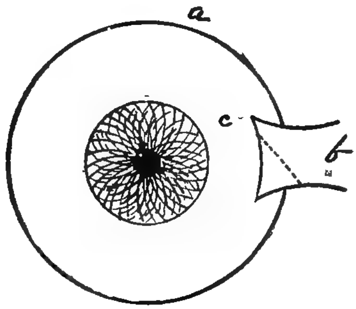

FIG. 79.—Oblique partial tenotomy according to Stevens.

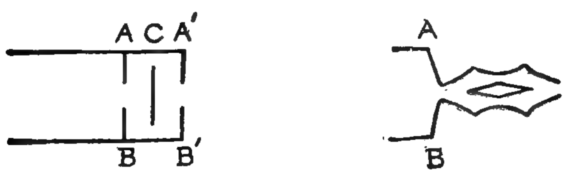

FIG. 80.—Partial tenotomy by three transverse incisions (Verhoeff).

Another method of lengthening the tendon without completely dividing it has been described by Todd (B 1850). The upper portion of Fig. 81 shows the lines of incision, and the lower portion the extension of the muscle which results. Evidently the principle is the same as in Verhoeff's operation.

It is proper to refer thus even briefly to the earlier forms of partial tenotomy. But every operator of experience tries one method after the other, and finally decides on the one which proves most satisfactory in his own hands.

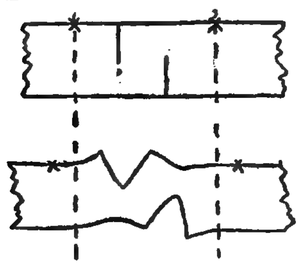

Fig. 81.—Lines of incision of Todd.

It has seemed to me that the simplest and most rational method of making partial tenotomy is to divide cautiously and accurately a portion of the fibers of the tendon close to its insertion. Thus we may make:

(*A*) Central partial tenotomy in which nearly all of the fibers in the central portion of the primary insertion are divided (Fig. 82).

(*B*) Lateral partial tenotomy in which the fibers of one edge of the principal insertion are divided (Fig. 83).

(*C*) Double lateral partial tenotomy in which all of the fibers of the principal insertion, except a small band in the center of the tendon, are divided (Fig. 84). These illustrations show the locality and extent of the incision.

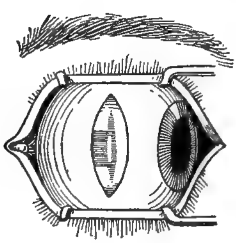

Fig. 82.—Central partial tenotomy.

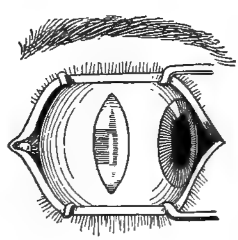

Fig. 83.—Single lateral partial tenotomy.

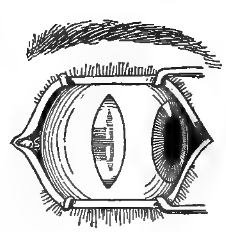

Fig. 84.—Double lateral partial tenotomy.

As the instruments used for making these forms of partial tenotomy and the technique employed are the same as for complete division of the principal insertion of the tendon, therefore the description of these instruments and of the technique can be considered in the section which follows this.

CHAPTER II.

DIVISION II.

SIMPLE TENOTOMY.

§ 1. **Definition.**—Simple tenotomy consists in the division of all the fibers of the primary insertion without division of any of the secondary insertions. Although this is really a complete and total division of fibers of the *primary* insertion, it is advisable to retain those two terms for the form of tenotomy to be described next. Simple tenotomy is what was intended by most of the earlier operators, although the procedure was designated in general as "tenotomy." That of von Graefe, Critchett, and others have already been referred to. Little or no attention was paid, however, to the secondary insertions.

§ 2. **The indications** for simple tenotomy are:

First. The correction of the deformity. Although this is not the most important reason, it was the one which first led to the operation, and is still the one which prompts parents to bring their children for examination. Upon the removal of this deformity the credit of the surgeon largely depends. The question therefore arises whether the deformity alone is a sufficient reason for advising the operation: In the case of a young woman—decidedly, yes,—but in men who pretend that they "don't care how it looks," and in all persons past early life, the opinions of the patient on this point are of quite as much value as are the ideals of beauty cherished by the surgeon.

The second and principal reason for making simple tenotomy is to obtain, if possible, binocular vision. The importance of this has already been considered in various aspects.

§ 3. **A Useful Method.**—Each operator at first tries the

text-book methods, until experience gradually suggests the plan which seems to him to have the maximum advantages with the minimum of the disadvantages. Therefore, it is perhaps worth while, after having referred to methods of other surgeons, to give a brief description of the plan which has seemed best to me. No claims of originality in method are made, and the form of the hook is only such as naturally suggests itself.

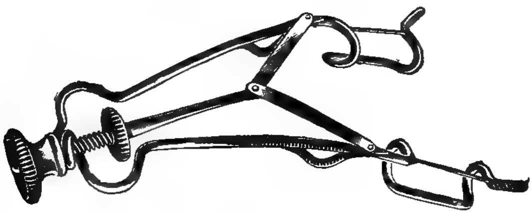

FIG. 85.—Noyes's speculum.

§ 4. **Instruments** for tenotomy. We have already seen that these have been gradually improved, although in some clinics we still find clumsy scissors and hooks which might better be used by orthopedic surgeons. Those which seem in general to be best adapted to the purpose are:

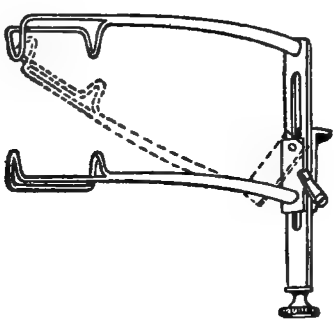

FIG. 85 (*a*).—Murdoch's speculum.

First. The speculum. With most operators I prefer the form first suggested in this country by Noyes (Fig. 85). But the model devised by Murdoch and modified by others has the great advantage that the patient cannot close the lids upon it, no matter how strong the fibers of the orbicularis

may be, whereas the operator can immediately release it if he wishes.

The speculum in the so-called Stevens case has too weak a spring. On two occasions in my experience a patient has deliberately closed the lids, and the performance came to a standstill until he saw fit to allow it to proceed. If this were to occur when introducing a needle, it might lead to disagreeable complications.

Second. A pair of delicate straight forceps, sometimes called iris forceps (Fig. 86).

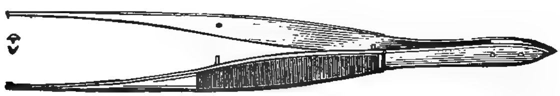

FIG. 86.—Small tenotomy forceps.

Third. Two graduated hooks. The form of these is important. The one used of late years and which I have learned to regard as essential to exact work, is much more delicate than that ordinarily employed. The off-set is not curved in the form of a hook, as is usual, but instead turns at a distinct right angle to the axis of the handle. It is a little over a millimeter in thickness, seven or eight millimeters in length, and each side of the off-set is graduated in millimeters by a minute nick. This is seen in Fig. 87.

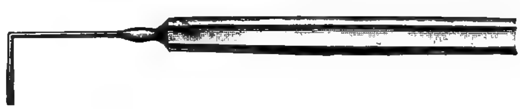

FIG. 87.—Tenotomy hook of the author.

The advantage of measuring millimeters with an actual measure and not by the eye is evident. It is always convenient to have a second such hook, if it may be so called. This second one may have the graduated off-set only about five millimeters long.

Fourth. Scissors (Fig. 88). These are firm and strong, with the ends sharp but not quite pointed. Those suggested by Stevens are also excellent.

Fifth. A needle-holder, light and small, with a catch which really catches and which can also be easily loosened.

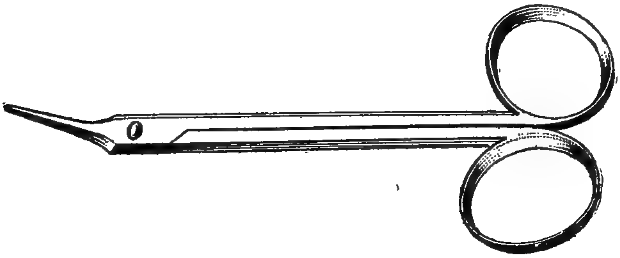

FIG. 88.—Scissors for tenotomy.

A very convenient form is seen in Fig. 89. Although it has long been used by the general surgeon, it is recent in opthalmology.

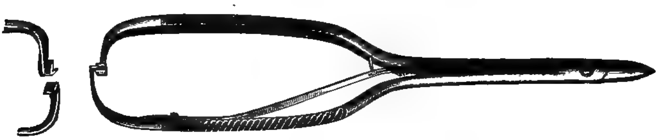

FIG. 89.—Needle-holder.

Sixth. A few fine curved needles with silk No. 00 or 1. Some operators prefer catgut sutures (Fig. 90).

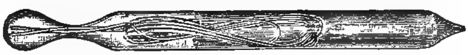

FIG. 90.—Prepared catgut.

These are of undoubted value in tucking operations and in some forms of advancement, but are not so necessary in closing the conjunctival wound of tenotomy.

§ 5. **Technique** of partial and of simple tenotomy. The eye having been placed thoroughly under the effect of cocaine, adrenalin 1:1000 is also applied and the speculum introduced. A fold of the conjunctiva is then pinched up in a direction parallel to the fibers of the muscle, and an opening made across them at a distance of about five or six millimeters from the margin of the cornea. This incision is then enlarged

until it measures six or eight millimeters from above downwards. The conjunctiva retracts, and with a pair of fine forceps the fibers of the connective tissue which lie just beneath the conjunctiva are also divided, leaving the tendon exposed at its insertion. This constitutes the first step in the operation.

The second step is the determination of the point of insertion of the tendon and its partial division. For this, as for any other form of tenotomy, it is essential to ascertain just where the tendon is inserted. It is not sufficient to estimate this point by the eye. Therefore, applying the graduated hook to the eye, we measure five and a half millimeters from the corneal margin. Under normal conditions that is the center of the tendon, the line of the primary insertion extending ordinarily about two and a half millimeters above, and also below. We mark this point either by its relation to some vessel or other spot, or pick up a few fibers of the tendon and divide them simply as a spot from which to measure.

The third step is the division of the fibers of the tendon. If a central partial tenotomy (Fig. 82) is desired, the central fibers are divided, the graduated hook is passed through this opening, and the incision is extended two millimeters or more above, and about the same distance below. The fibers of the tendon should of course be divided as close as possible to the globe.

If a single lateral partial tenotomy (Fig. 83) is desired, as in the case of a hyperphoria or hypophoria, we measure from the center of the insertion about two and a half millimeters to the edge of the principal insertion, and make a small opening through there. The graduated hook is entered, care being taken not to disturb any of the other insertions, and the tendon is divided slowly and cautiously across, for two, three or four millimeters, according as tests at the time seem to indicate.

When a double lateral partial tenotomy (Fig. 84) is wished for, a similar opening and small incision is made at each edge of the tendon, close to its insertion.

When a complete division of the principal fibers is desired,

they are simply divided in the same way entirely across (Fig. 91). The accessory fibers which constitute the secondary insertion are, however, carefully avoided.

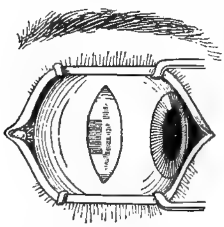

Fig. 91.—Simple tenotomy.

The fourth, and very important part of this and of all other tenotomies (and of advancements also) is the measurement, as we proceed, of the results up to that point. No matter how accurately the incisions may be made, or how exactly they correspond with the average anatomical conditions, still the actual changes in the position of the globe should be frequently tested. This means that before we reach the limit which is theoretically desirable for the incision, the speculum should be removed, the eye cleaned, and tests made. This is easy in cases in which we have been able already to obtain binocular vision. When that was not, and is not possible, we should make as accurate objective measurements as possible. If the patient can walk into an adjoining dark room, a measurement can be made of the position of the corneal reflexes, or roughly of the arc of rotation (as that is possible), with the flattened tangent scale. By regulating the dose of cocain, the anæsthesia can be continued a longer time, and operation and tests can be alternated until the desired result is obtained.

The object in most earlier tenotomies was to make an operation and be done with it—the quicker the better. The modern object is to obtain a good result. To divide that tendon in any way, is ridiculously simple; to divide it properly, is one of the most difficult procedures in ophthalmic surgery.

The final step in tenotomy of any form consists in the closure of the wound. This is merely to draw the conjunctiva together with a suture. Some prefer catgut, others like silk as well. There is not much choice. The only point is to make the suture secure and keep the ends off the cornea.

The after treatment consists simply in a light bandage,

and occasionally bathing with weak antiseptic washes. The stitch can usually be removed in three or four days.

§ 6. **The Immediate Effect of a Tenotomy** depends on:

(*A*) The amount of correction. In some cases there is apparently no change—especially if the division of the tendon has been slight. But rough tests are not sufficient to determine this. Exact measurements, subjectively or objectively, will show a change of six or eight degrees or more, which without those tests would hardly be suspected. If ophthalmologists were in the habit of making such measurements more frequently, they would see the advantage of slight changes produced by tenotomies or advancements.

(*B*) As to the character of the correction, a central or double lateral partial tenotomy naturally simply weakens the muscle. If the tendon is left attached by only a few fibers at one edge, sooner or later the globe tends to turn slightly up or down. But such a change cannot always be demonstrated immediately after operation.

§ 7. **The ultimate effect** of a partial, or simple tenotomy is nearly always greater than the immediate, as regards both the amount and the character of the deviation. This will be referred to later more in detail.

CHAPTER II.

DIVISION III.

TOTAL TENOTOMY.

§ 1. **Definition.**—This is the division of all the fibers of both the primary and the secondary insertions. It is tenotomy with backward displacement—the *rucklagerung* of German text-books.

§ 2. **It is indicated;**

(*A*) For enucleation and before advancement.

(*B*) As an adjuvant to advancement of the opposing muscle. Thus, for extreme exotropia, we usually find it necessary to divide all of the fibers of the external, if we wish to advance satisfactorily the internal rectus.

(*C*) Total tenotomy alone is also indicated for heterotropia. In that case:

(*a*) The deviation should be large; and

(*b*) The arc of rotation also large.

(*c*) The deviation should be distinctly of an active rather than of a passive type.

(*d*) The vision of the deviating eye should be quite good, and preferably not with a high degree of ametropia.

(*e*) The patient should not have passed his early teens. Evidently considerable care is necessary, lest by separating the insertion entirely we lessen the power of duction too much, and permit the eye to "turn the wrong way."

§ 3. **The instruments for total tenotomy** may be the same as those described for partial or for simple tenotomy. But it is unnecessary to have them so delicate. We require of course the same speculum, but in making total tenotomy it is much more convenient to use a pair of forceps which is

strong, quite large, and provided with three or four teeth (Fig. 92).

FIG. 92.—Strong forceps for total tenotomy and operations for advancement.

In this operation we do not need the delicate hook marked off in millimeters; the larger and more clumsy one usually sold as the "strabismus hook" is just as useful.

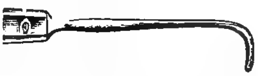

FIG. 93.—Strabismus hook much reduced in size.

Any pair of scissors will do, if reasonably small and not too sharply pointed. It is desirable for this operation, as in all others on the muscles, to have a good needle holder, and the one already figured is ordinarily used by those who have had experience with it.

§ 4. **The technique of total tenotomy** is often confused with that of partial or simple tenotomy. But they are entirely different. The former is a microscopic dissection, in which the division of almost every fiber is of importance. The latter is simply the complete division of *all* the fibers of a tendon. In these cases one of the earlier methods is usually adopted as the general plan, but an operator may cut his way with almost any instruments through any of the fibers. When he does obtain thus a really good result, his pride in his skill is only equalled by his contempt for accurate methods, little appreciating that with this procedure, if the case happens to be a suitable one, he could not easily make a mistake. In as much as the object of this operation is to obtain the maximum effect, a question may arise as to whether the wound should be closed with stitches. But if the muscle has been properly freed from connective tissue, the position of the globe will not be materially altered by closing the conjunctival wound.

Not to do so leaves a considerable space to granulate, an unsightly mark in the process of healing, and a scar which, to the professional eye at least, suggests the work of a bungler.

On the day following the operation, if measurements again show that a sufficient effect has not been produced, it is easy to snip these superficial stitches.

§ 5. **The after treatment** is simple and practically the same as for the other forms of tenotomy, when no advancement of the opposing muscle has been made. When that has been done, however, considerably greater care, on about the same plan, should be continued for several days.

CHAPTER II.

DIVISION IV.

TOTAL TENOTOMY WITH STRETCHING OF THE MUSCLE.

When orthopedic surgeons wish to obtain the maximum effect of a tenotomy, they sometimes dissect out the tendon, draw on it with considerable force, and then divide it. It is also well known that if much traction is made on an ocular muscle, during operation, any tests of the position of the eye, soon after, are quite unreliable (B 1875).

It was perhaps some such fact which first prompted the effort to lessen the action of a rectus simply by stretching its fibers. That was practiced to a certain extent, a third of a century ago or more, but was soon forgotten, probably because, cocain not having been discovered at that time, the method was painful and unsatisfactory. With the assistance of a local anæsthetic the effect of at least moderate stretching of the recti can be easily seen. To do this we apply cocain, and then, with a pair of strong fixation forceps catching the conjunctiva and the muscle beneath it, rotate the eye as far as possible in the opposite direction. In some cases even this seems to lessen the contractile power of the muscle, as we can see by the usual tests of the static position made before and after the experiment.

This effect of stretching a rectus without tenotomy is referred to because of the use made of the principle by Panas in conjunction with total tenotomy (B 1872).

He found cases of esotropia, as we all have, in which, even after making total tenotomy of both interni, some esotropia still remained. Therefore, after exposing and isolating the muscle, a large hook was passed under it, and the point of insertion of the internal rectus was rotated forcibly toward the

outer canthus. When we remember that the tensile strength of a rectus does not much exceed two and a quarter kilos, evidently some care must be exercised lest the muscle be torn (Vol. I, p. 202).

The fact which interests us now is that this stretching of a rectus muscle tends to lessen its action, at least for a time. The operation suggested by Panas has been followed by several operators, especially in America by Roosa, Wootton, and others. The principle has been applied, however, to stretching the internal rectus forcibly in this manner, but not dividing it, when advancement is made of the external rectus. This will be referred to again in connection with operations of advancement (B 1872-1879 and 1916).

CHAPTER II.

DIVISION V.

TENOTOMY WHICH ALSO PRODUCES TORSION.

§ 1. **Definition.**—This is a tenotomy, partial or total, which produces a change in the position of the horizontal and also of the vertical axis.

§ 2. **Indication.**—Such an operation may be indicated when there exists a decided extorsion or intorsion, or either of these conditions with es- or ex-otropia, and when relief cannot be obtained by any other treatment.

§ 3. **Is it possible** to produce a torsional effect by any operation on the recti muscles? That will be answered in the affirmative by any practitioner who will review his experience. He can remember that on several occasions when he intended to make a simple tenotomy or to advance a muscle he has by mistake loosened or tightened one edge of the muscle more than the other, and as a result the position of the vertical axis or even of the entire globe was altered. The result thus obtained unintentionally can be produced at will by proper tenotomy.

§ 4. **Technique.**—The simplest way to tip the globe is by a lateral partial tenotomy. But the effect of this is often so slight that, as has been said, it is sometimes impossible to be sure that any change in the position has taken place, at least not immediately after the operation. Several other methods have been suggested of late years for making total tenotomies, which not only lengthen the tendon but also produce a torsional effect. They are:

(*A*) Stephenson's operation. The tendon having been freely exposed, is divided by two short transverse incisions and one longitudinally, thus forming, as it were, a step of a

stair, as in Fig. 94 (A). The divided ends of the tendon or muscle are then united with two sutures.

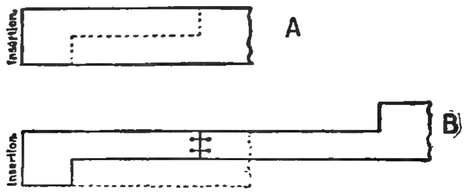

FIG. 94.—Tenotomy with oblique correction (Stephenson).

(*B*) Landolt also advises procedures somewhat similar to this. One method proposed by him is quite similar to that of Stephenson, Fig. 95 (A), except that the extreme ends of the divided portions are not stitched together, but the threads are introduced as in Fig. 95 (B). This allows less retrac-

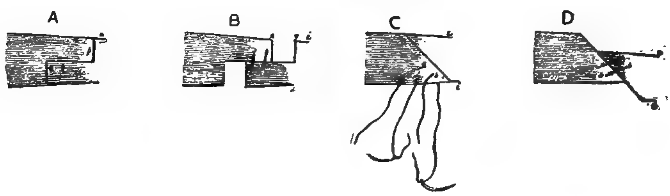

FIG. 95.—Tenotomy with oblique correction (Landolt).

tion. Landolt also divides the tendon obliquely (Fig. 95 C and D), and by uniting the projecting ends, extension of the muscle with a torsional effect is produced.

(*C*) Jackson's operation (B 1881) consists in a transplantation of the tendon of a superior rectus to a point of insertion nearer the temporal side and farther back than the original insertion.

It is indicated especially in cases of paresis of the superior oblique. That muscle produces, as we know, intorsion and a tendency of the center of the cornea to turn down and out. When its action is impaired, its effects must be supplied, if at all, by the superior, inferior, and external recti. There are good theoretical reasons, therefore, for transplanting the

superior rectus in, and slightly backward, increasing its power to cause intorsion and diminishing its power to rotate the cornea upward. Moreover, the results appear to have amply justified the procedure.

In order to make Jackson's operation, a fold of the conjunctiva is lifted up over the insertion of the superior rectus in a direction parallel to its fibers and the conjunctiva is divided across the fibers about ten millimeters from the cornea. This incision is extended outward in the direction of the dotted line *a b* (Fig. 96). The hook is then passed under the tendon, and it is lifted free from the sclerotic.

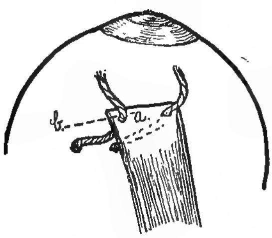

FIG. 96.—Jackson's operation. Early stage.

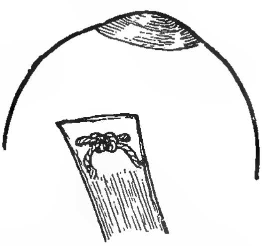

FIG. 97.—Jackson's operation. Completed.

In the second step, a very fine curved needle is passed through the tendon a few millimeters behind its insertion, not far from its inner edge. The needle is then made to enter the episcleral tissue, at a point beneath the muscle, near the outer edge. It passes through this tissue, as well as possible along the line *a b*, for four or five millimeters, and emerges. It is then drawn through. Again entering the under surface of the tendon at a point near its outer margin, it is drawn through a second time. The tendon is divided as close to the insertion as possible, and when the ends of the thread are tied, the muscle is slid into its new position as in Fig. 97. The schematic representation of this operation, and that of Jocqs and Critchett, are modified from the suggestive illustrations of Grimsdale and Brewerton.

CHAPTER II.

DIVISION VI.

EFFECTS OF TENOTOMIES.

§ 1. **Balancing the Effects.**—When should we make tenotomy on one eye only, and when should the effect be divided between the two? That is impossible to answer definitely. In a certain way, every case is a law unto itself, depending upon the factors already mentioned. But it can be stated, as a general rule, that if the deviation in any direction exceeds ten or fifteen or surely twenty degrees, we are then quite safe in dividing the operation between the two eyes. There is nothing new in this statement. Long ago, in that most practical text-book by Wells, he said that "if the deviation exceeds two and one half or three lines we must always divide the operation between the two eyes." As a rule of thumb that was excellent, but it is often advisable, when the deviation is considerably less than that, to make the correction partly on one and partly on the other (B 1885).

In dividing the operation thus between the two eyes do we gain anything beside the smaller laceration necessary? Most assuredly, yes. What we strive for is perfection—not when the eyes are in one position only, but in any which they may occupy. In certain cases it is true the perimeter may show a greater limitation of the arc of rotation in one direction than in the other, and when that is the case, we naturally deal with the imperfection by making a corresponding correction in that eye as compared with the other. In such cases a simple or even a total tenotomy in one eye, with perhaps nothing done to the other, is quite sufficient; but in the majority of cases, where the limitation of the field of fixation is about the same in each eye, it is

unquestionably better to retain the normal balance between the two, keeping both arcs of rotation equal.

§ 2. **Under-Correction is Desirable in Early Life.**—In all operations for tenotomy, caution should be exercised not to make an over-correction. After a tenotomy of an internal rectus, even though that be insufficient at first, the tendency of the axes is outwards rather than inwards. This is also seen in the cases of esotropia which correct themselves. If, therefore, in early life a full correction is made of an esotropia by tenotomy, that often means a considerable exotropia in middle life.

The typical operation, therefore, for children, consists in allowing a trace of abnormal convergence to remain uncorrected. It is true such a result is apparently not creditable to the surgeon, and usually far from satisfactory to the parents. Indeed, the entire family circle is apt to protest against this partial completion of what they consider a finished operation. But if the object to be attained by the operation is properly and fully explained before, the more intelligent parents are satisfied. It is often embarrassing to the surgeon to be confronted after the operation by a deformity which he knows he could correct if so inclined. On the other hand, to yield to the wishes or protestations of parents, when his judgment tells him that should not be done, is an evident wrong to the patient. Fortunately it is usually possible for every practitioner, after a few years, to recall numerous cases of his own in which such a convergence was allowed to remain in childhood with the production of a perfect result ultimately. In every locality there are also cases in which some time-serving operator made a full correction at once, and the result has proved a life-long regret to the patient.

After childhood or early youth is past we need not be so timid in regard to making a full correction. If the patient is fifteen or twenty or over, it is sometimes impossible to bring both eyes into action, and the hope of a perfect result must be entirely abandoned. By that time, therefore, we are fairly safe in making the correction complete. Indeed, it may be stated as a rule that the nearer the

patient is to adult life the safer it is to make a complete correction.

§ 3. **The Four Stages Following Tenotomy.** — After having made any of these various forms of tenotomy the eye passes through four stages, as regards the position of the visual axes. These can usually be recognized even without accurate tests of any sort. They are:

1st. The position immediately after the operation. This stage lasts a few days or even for weeks.

2d. There is a tendency for the eye to return to the position which it occupied before the operation. If the surgeon has forgotten or omitted to mention this before, anxious mothers are always sure that the operation was wrong, and that the eye is "going back"—some indefinite distance. Various explanations have been offered to account for this tendency of the eye. It is often called "a habit." Whenever a deviation has existed (an abnormal convergence, for example), the nerve centers being long accustomed to a given stimulus, or the retina being in the habit of centering the image in a certain spot, have a tendency to resume the former relation to as great an extent as possible. This explanation undoubtedly accounts for certain phenomena.

But it is probable that the mechanical explanation is nearer the truth. This takes into account the fact that the over-balancing group of muscles had become strong and well developed by constant use. So as soon as one of this group, after having been divided, reattaches itself, it is able again to overcome its opponents. One of these causes, or perhaps both together, combine to restore the original deviation. Sometimes this is hardly apparent, sometimes it is very pronounced, lasting from a few months to even a year or more.

3d. After that period has passed, the third stage begins, and the visual axes tend to resume the position which they occupied immediately after the operation. This process goes on slowly but steadily. That also may require a few months or perhaps a few years.

It is not easy to analyze the different causes which produce this third effect. The probabilities are, however, that the

mechanical explanation is again the most reasonable. For as the muscle which was divided has slipped backward on the globe, the power of traction there is not as great as in the position which it formerly occupied. This is especially the case when the internal rectus has been divided. It then not only slides farther back on the globe, but its opponent acts to much greater advantage.

However that may be, in this third stage the visual axes not only tend more and more away from the position which they occupied before the operation, but unfortunately they swing sometimes still farther than we wish and we find that we have obtained an over-correction. Thus an original esotropia may show parallel axes in the first stage, an esotropia in the second, and exotropia in the third. This seldom occurs, however, if we can obtain and retain binocular vision.

4th. Finally, after the several months or more which this third stage occupies, the visual axes assume the position which they occupy permanently. In the favorable cases and those in which each eye can be brought into use, the axes are parallel for distant vision and there exists a normal power of convergence.

CHAPTER III.

ADVANCEMENT.

DIVISION I.

DEFINITION AND GENERAL CONSIDERATIONS.

§ 1. **Definition.**—Advancement of a rectus muscle means a shortening of its line of traction. The methods of doing this will be considered later.

§ 2. **The indications** for some form of advancement are:

First. When an apparent or a latent deviation is due *entirely* to insufficient action of one muscle or group of muscles, and when improvement or cure can not be obtained by non-operative treatment, suitable advancement is necessary to the best result.

Second. When an apparent or a latent deviation is due *partly* to insufficient action of one muscle or group of muscles, together with excessive action of the opponents, suitable advancement gives the best results, but improvement can also be obtained by tenotomy. As these cases are the most numerous of all, many an operator, careless as to both diagnosis and operation, blunders through a tenotomy, apparently cures the deformity, imagines immediately that he has obtained the best result possible, and proclaims loudly against the necessity of advancement in any form. These two propositions concerning the indications for advancement will be elaborated later. But if we recognize at this point the underlying principle as to when this operation should be done, we can consider more intelligently *how* it should be done in order to obtain the minimum, a moderate, or the maximum effect.

CHAPTER III.

DIVISION II.

ADVANCEMENT WITHOUT TENOTOMY (TUCKING)

§ 1. **Definition.**—This operation consists, as the name implies, in a folding of the tendon upon itself. As the procedure is comparatively simple and also as it produces less change in the position of the visual axes than do the more usual forms of advancement, it is desirable to direct our attention first to it. The idea of shortening a muscle without dividing its fibers is of comparatively recent origin. The suggestion seems to have been made first by de Wecker (B 1910), but was rather lost sight of until, in the process of ophthalmological transmigration, the operation has reappeared in American literature, having been baptized with the euphonious name of "tendon tucking."

§ 2. **Valk's Operation.**—One of the earliest methods used in this country, and one which at least has the advantage of simplicity, was proposed by Valk. He makes two incisions, at right angles to each other, over the tendon (Fig. 99), and passing what he calls "a pair of strabismus hooks" (Fig. 98) beneath the muscle, the tendon is lifted on them

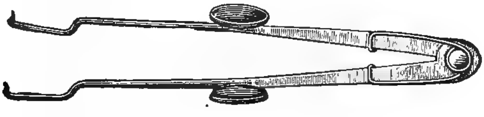

FIG. 98.—Valk's double strabismus hooks.

away from the globe. A sterilized cat-gut ligature is passed through the lower portion of the tendon near its insertion from without inward, and then through the muscle as far

backward as desired. From that point it crosses the muscle at a right angle, and once more as the needle dips from without inward into the muscle it emerges in the tendon, opposite the point where the suture first enters. When the suture is drawn together it forms the so-called "tuck" (Fig. 100). This leaves rather an ugly projection on the globe, which, it is true, usually disappears after a while, but which occasionally remains as a decided deformity (B 1913).

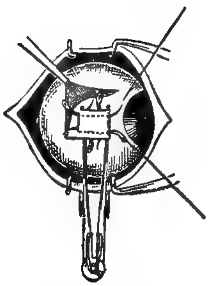

FIG. 99.—Valk's operation. Early stage.

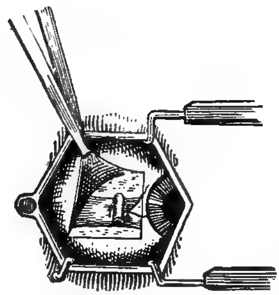

FIG. 100.—Valk's operation. Later stage.

§ 3. **Green's Operation.**—He makes an elliptical incision in the conjunctiva as seen in Fig. 101 II *a*. A corresponding part of this membrane with the adjacent tissue is laid back, exposing the muscle, which is then isolated and lifted on a broad hook. In order to fold the tendon upon itself a special form of forceps is employed, as is seen in Fig. 102 III. As the two ends of these forceps slide past each other they bend the muscle on itself in the manner shown. Having done this, a fine thread is selected, armed with two needles. One of these needles is passed from within outwards through the three layers of the tendon near one of its edges, and the other needle passed in a similar manner, from within outwards, through the three layers of the tendon near its other edge. The two ends of the suture are then tied as seen in Fig. 102 (B 1915).

As that tendon tucker does not have a millimeter measure on the set screw, the operator can only guess the amount which the muscle is advanced. Also, as this operation requires the muscle to be folded on itself twice, it is applicable only in cases where a very considerable correction is desired. While the method looks well in a diagram, any one who has tried to make such a folding of the muscle for a slight correction, and then to find room also for the introduction of a needle and thread between the bands of the forceps, knows that the difficulties are by no means small.

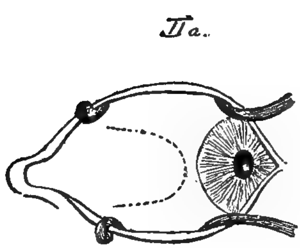

FIG. 101.—Conjunctival incision in Green's tucking operation.

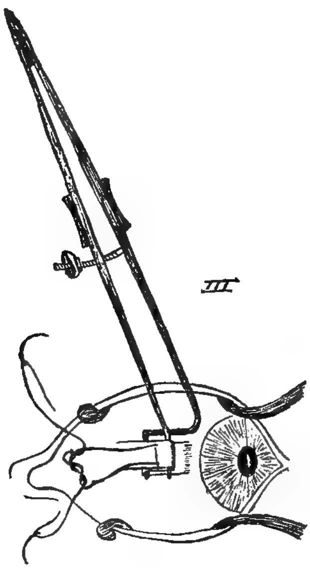

FIG. 102.—Green's forceps folding the tendon.

Todd uses a similar form of tendon tucker but with a graduated set screw. He also folds the muscle into three layers (B 1921).

§4. **Jocqs' Operation.**—In 1904 Jocqs advised a method of folding the muscle on itself which is a little different from tucking. He threads two needles on one suture, and anchorage is first secured by passing one needle through the

episcleral tissue and near the edge of the cornea (Fig. 103). An elliptical piece of conjunctiva is removed in a direction parallel to the fibers of the muscle. The latter is then lifted with a pair of strong forceps. One of the needles is passed through the fibers of the muscle in a direction obliquely backward, the other also obliquely backward, the points where the needles emerge being at least three millimeters apart. On tying the stitches, the muscle is puckered up as it were, and brought forward (Fig. 104). The operation is

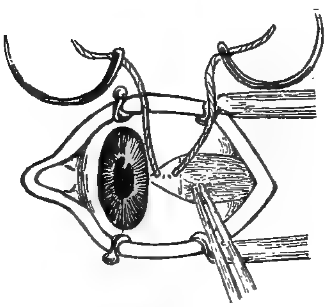

FIG. 103.—Jocqs' operation. Suture introduced.

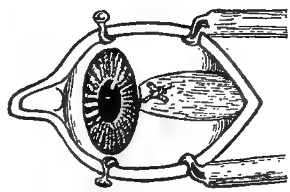

FIG. 104.—Jocqs' suture tied.

comparatively simple, but has the objection common to all in which anchorage is made in the episcleral tissue (B 1922).

§ 5. **Author's Method.**—A convenient tucking operation, and one which I have found to have as few objections as any, is briefly as follows:

First. The conjunctiva is incised as for tenotomy, but more freely, and the tendon is separated from all connective-tissue fibers.

Second. The number of millimeters of shortening which are desired having been decided by earlier measurements, the set screw of the tucker (Fig. 105) is placed at a point which allows its central arm to rise half that number of millimeters above the other two arms and about a millimeter beyond (to allow for the thickness of the instrument). Then the single arm of the tucker is passed beneath the tendon, the other two above it, and closing the spring of the tucker, the tendon is drawn up into the slit between the two

arms, just the number of millimeters desired. The fold in the tendon is then secured by a ligature of catgut at each edge.

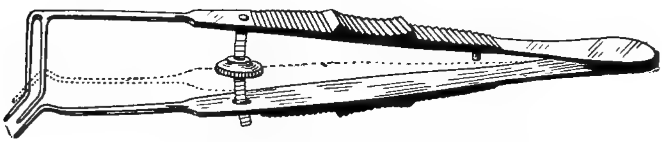

FIG. 105.—Tendon tucker of the author.

The opening in the conjunctiva closes itself by the tucking, or if not, a small superficial suture will suffice. The simple after-treatment is the same as for cases of tenotomy. Usually the stitches in the tendon absorb. Or if they do not, the one in the conjunctiva is removed and then one or both of those in the tendon. They are of little or no importance after the first week, for by that time the parts are quite firmly glued together by exudation.

The advantages of this operation are:

First. The tendon is folded on itself only once. Therefore the stitch passes through but two layers, instead of three, as in the earlier operations. This simplifies the procedure, and also reduces the size of the bunch, which is the principal objection to this group of operations.

Second. The amount of the shortening can be regulated with the utmost exactness; and

Third. The direction in which the stitches are introduced makes such a step safe and easy.

On the other hand, this has a disadvantage, to some degree, which it shares with all the other methods of tucking. A considerable dissection of the tendon is necessary. When the stitches do not absorb, annoyance is often given to the patient by the efforts to remove them, and the inevitable bunch which remains disappears but slowly.

CHAPTER III.

DIVISION III.

ADVANCEMENT.

§ I. **Definition.**—A true advancement of a muscle consists in the division of the primary and all of the secondary insertions, and bringing forward the muscle with or without the capsule to a point nearer the cornea. This procedure may or may not be accompanied by a resection of the muscle or by a division of the opposing muscle. Those two procedures are only adjuncts to advancement.

In order to make the definition clearer and also to establish a standard of excellence by which to determine the practical value of each operation, it is desirable first to see what steps must be taken to accomplish the object. They are:

First. After having exposed the muscle, either before or after dividing it, we must in some way attach a suture of some kind to the muscle, or to the muscle with the surrounding tissue.

Second. We must obtain a safe and secure anchorage for the suture or sutures. This may be by one suture extending straight forward to the edge of the cornea, there passing through conjunctiva or episcleral tissue, or both. Or some of the sutures may branch off obliquely from the point of incision also through the conjunctiva or episcleral tissue or adjacent muscles.

Third. We must regulate, if possible, during the operation, the amount of advancement which is made, by tightening or loosening a simple knot, or by making a loop with the knot, so as to obtain in addition the effect of a pulley.

Fourth. In certain cases we must permit the advanced

end of the muscle to slide of its own accord or to be pushed into the position which proves to be the most desirable for that muscle in that individual.

Fifth. When the sutures are introduced in certain positions it is desirable to have them of a material—cat-gut, for example—which absorbs, or if not, to place them so that after the swelling sets in they can be removed with the minimum amount of pain and discomfort.

§ 2. **Evolution of Advancement.**—The idea of increasing the action of a muscle by shortening it was originally the result of myotomies or of excessive tenotomies. As Dieffenbach was the first to perform tenotomy, he was also one of the first to see the necessity of introducing a suture into a muscle which had retracted too far (B 1924).

In 1849 Jules Guérin drew the muscle forward with a single thread in a similar but more exact manner (B 1901).

Von Graefe accomplished the same purpose by a somewhat different method. In order to advance the internal rectus, for example, he divided that muscle close to its insertion, and then attaching a thread to the tendon of the external, rolled the globe in and made fast the other end of the thread on the nose (B. 1807).

§ 3. **Varieties of Advancement.**—The student whose attention is called for the first time to operations for advancement is always surprised at the number of procedures which have been proposed. Even practitioners of large experience are often confused by the multiplicity of methods already on record and by those which are being constantly described as new. This variety of method means, as always, that the demand for treatment of this kind is urgent, but that no one form thus far is satisfactory. At first glance it seems impossible to arrange these different operations in any order, as they merge into each other by imperceptible gradations.

But if we disregard their details, we can place them in two or three groups according to the degree of development of the idea on which this operation was based. At first there was the natural desire to bring forward the muscle only. A little later, came the idea of advancing not only the muscle

but its capsule, and the parts that were naturally attached to it; and still later, the suggestion to make the suture act as a pulley. Following this general plan we can therefore divide these operations into three groups—those in which an effort was made to advance

(*A*) The muscle alone, or

(*B*) The muscle with the capsule, or both with the connective tissue and conjunctiva, or

(*C*) To advance muscle, or muscle with capsule, by a pulley suture.

§ 4. **Adjuncts to Advancement.**—The effect of an advancement may be increased by

(*A*) **Tenotomy of the Opposite Muscle.**—This is advisable in almost every case, for a slight advancement thus produces as great a change in the position of the globe as would a greater advancement without the tenotomy. Evidently, too, there is not as much traction on the sutures. But it is essential to have the form of the tenotomy bear some relation to the amount of the advancement, and especially to the condition of this opposing muscle. Failure to do this is a frequent cause of disappointing results.

For if a paresis, or certainly if a paralysis of one muscle is very marked, and we make a tenotomy of its opponent, the arcs of rotation in both directions are necessarily lessened after the partly paralyzed muscle is advanced. Even a perceptible exophthalmos may result. Therefore a good general rule is

(*a*) If the arc of rotation is large in the direction of the deviation, or if other tests show that those muscles retain at least their normal strength, then a total tenotomy is safe; but

(*b*) If that arc is small, or if other tests show that the muscles do not retain a considerable amount of strength, then a simple tenotomy only should be made, or no tenotomy at all.

In cases of exotropia a careful measurement of the lifting power of the adductors is apparently of real assistance in our decision whether to make a total, or a simple tenotomy, or none at all.

It should also be remembered that when tenotomy is

made for this purpose, its effect can usually be somewhat increased if the muscle is first stretched as Panas advised. But in doing this the tensile strength of the muscle should not be exceeded (Vol. I, p. 201).

(*B*) **Resection of the advanced muscle** is another modification of these operations which is usually advisable because

(*a*) The effect can be increased. As the insertion of the internal rectus, for example, is only five or six millimeters from the cornea, if the advancement desired exceeds that amount, resection is an evident necessity.

(*b*) The cosmetic effect is better. By resection we remove the unsightly bunch which otherwise is apt to show beneath the conjunctiva.

§ 5. **Indications.**—The question when we should make an advancement in preference to a tenotomy is such an important one that its consideration is deferred until after all the phases of advancement have been studied. But it is proper to observe in passing that advancement in some form is always advisable if the deviation is distinctly of the paralytic or passive type, and often if of the mixed type.

§ 6. **The instruments** used by different operators differ slightly. It is essential of course to have:

A speculum.

Strong toothed forceps.

One or two strabismus hooks.

Scissors which are delicate but not pointed.

Most operators since the time of de Wecker and Prince have used a large clamp for the muscle. An improved form of this will be mentioned later.

§ 7. **Precision in Advancement.**—We have already seen that if the action of a muscle is normal, a change in its position of one millimeter corresponds to a change of five degrees in the position of the visual axes. Also that for an active heterotropia a proportionately small tenotomy should be made, but for passive heterotropia a proportionately large advancement. This principle should be kept in view as much for advancement as for tenotomy, and what has been said concerning the latter need not be repeated now.

CHAPTER III.

DIVISION III.

SUBDIVISION I.

Advancement of the Muscle Only.

Although the very first operators, like Dieffenbach and Guérin, had in mind the bringing forward of the muscle itself, their methods were not well developed. Coming at once to the more modern form of advancement we may glance at

§ 1. **Williams' Operation.**—Fig. 106 (B 1906).

The conjunctival incision is over the muscle and parallel to its fibers. The muscle is then isolated, a suture passed through it, its tendon resected, each suture anchored in the episcleral tissue near the cornea and the ends tied.[1]

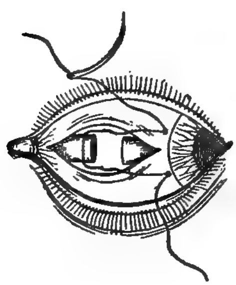

FIG. 106.—Williams' operation.

This operation has the disadvantage of all of its class in which the anchorage is in episcleral tissue, and in addition this suture is apt to slip out of the muscle.

§ 2. **Valude's operation.**—Fig. 107 (B 1935).

The conjunctival incision is a semicircle over the insertion, the convexity being directed backward. The muscle having been isolated, two sutures, each having two needles, are introduced as seen in the figure. The tendon is divided not only across, close to its insertion, but is split longitudinally for a few millimeters. One end of each suture passes backward through the conjunctiva. The other end, advancing obliquely toward the cornea, is anchored in the conjunctiva and episcleral tissue. When the ends of each suture are tied, one part of the tendon is drawn upward and the other portion downward, close to the edge of the cornea.

[1] In this and the other figures it is understood, of course, that where a suture is indicated by a dotted line, it then runs beneath the tissues.

This operation has the advantage of bringing a large freshened surface forward, but it has the disadvantage that

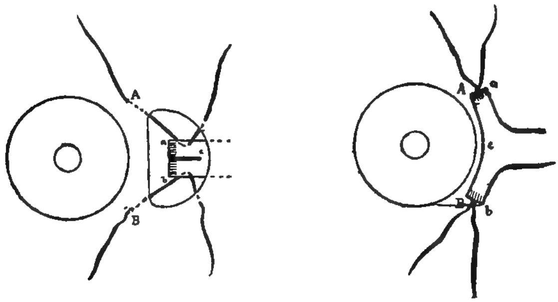

FIG. 107.—Valude's operation.

the procedure is somewhat difficult to execute, and these extending arms of the muscle naturally show themselves as a projection underneath the conjunctiva.

§ 3. **The Double-Knot Operation.**—Fig. 108 (B 1951, p. 492).

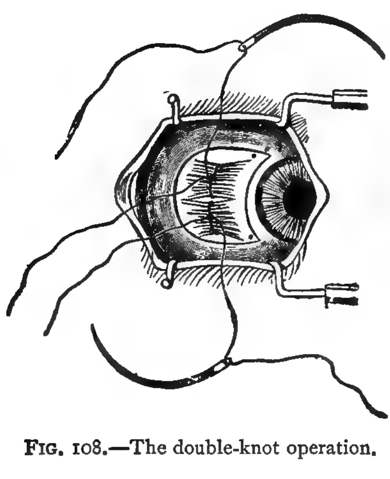

FIG. 108.—The double-knot operation.

This is the one figured by Swanzy,. de Schweinitz, and in most modern American text-books. The line of incision in the conjunctiva and the general direction of the operation are seen in Fig. 108. The muscle having been isolated and lifted up, one needle, passing from within outward, penetrates

it near its center. That suture is drawn through and tied firmly around the corresponding half of the muscle. Another needle on another thread follows a corresponding course, and is tied around the other half of the muscle. Each needle is made to traverse the episcleral tissue along the dotted line indicated in the diagram. The muscle is then divided at its insertion, resected if necessary, and each half of the muscle drawn forward to the place where it belongs.

It is an excellent procedure of its kind, and is frequently used, especially in America.

CHAPTER III.

DIVISION III.

SUBDIVISION II.

Advancement of the Muscle with its Capsule or other Adjacent Tissue.

§ 1. **Critchett's Operation.**—Figs. 109 and 110 (B 1956).

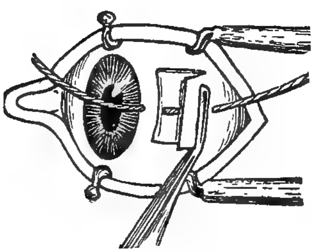

FIG. 109.—Critchett's operation. Early stage.

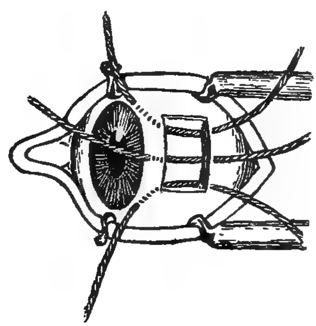

FIG. 110.—Critchett's operation. Later stage.

This was one of the earliest methods for advancing the muscle together with the capsule. The incision in the conjunctiva extends along three sides of a quadrilateral, allowing a flap to be turned back over the muscle. The latter is isolated. Then grasping it with a hook, together with the tissue lying above it, the muscle is divided near its insertion,

and together with the capsule and overlying conjunctiva, all are turned back from the globe.

The next step is the introduction of the sutures. A thread having been armed with two needles, one of them is passed through the muscle from within outward, transfixing all of the tissues. The second needle, being directed toward the cornea, passes into the episcleral tissue so as to obtain a firm anchorage for the suture in that position. In a similar manner, two other sutures are introduced parallel to the first one, except that their median ends pass slightly upward and downward, respectively. When these three sutures are tightened they draw the muscle with the capsule and the conjunctiva forward into a new position.

§ 2. **De Wecker's Operation.**—Fig. 111 (B 1957).

The conjunctiva over the area shown in the figure is removed entirely. Then after having laid bare the muscle almost as far as the caruncle, it is isolated and caught in

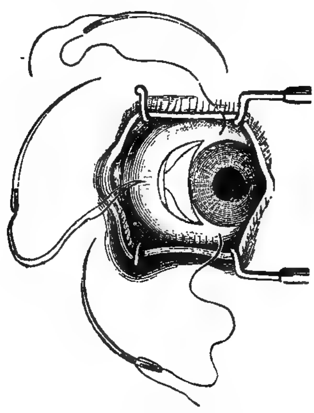

FIG. 111.—De Wecker's operation.

broad forceps bent at an angle, or what de Wecker called his large hook. With this it is held securely, together with the adjacent tissue, and the tendon is divided. The large hook is handed to an assistant who holds the muscle and the conjunctiva, as it were, suspended. This completes the first stage.

For the second stage of the operation, a thread is armed

with three needles. The central one is made to enter the center of the muscle, passing from within outward through muscle, tendon, and conjunctiva. The needle attached to one end then passes under the conjunctiva through the episcleral tissue near to the vertical meridian of the cornea.

The needle attached to the other end follows a corresponding course. The three needles are then cut off, and the corresponding ends of the two sutures are united.

§ 3. **De Wecker's Modified Operation.**—Fig. 112 (B 1888).

The conjunctival opening is represented by the space *a c c b*. A suture is threaded with two needles, and the muscle having been grasped, drawn forward, and isolated, one of the needles is thrust downward and backward, entering the upper border of the muscle near the point *c*. Then emerging

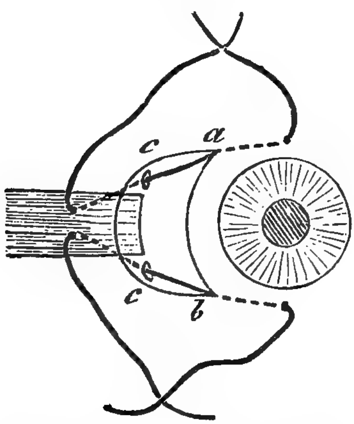

FIG. 112.—De Wecker's modified operation.

at some distance below and backward, that needle is drawn through. The other needle on that suture, passing under the conjunctiva at the point *a*, is pushed through the episcleral tissue to a point near the vertical meridian. These two sutures are united, but not tied firmly. A similar disposition is made of the other suture with its two needles.

When both sutures are in place they are tightened, and

with the aid of an assistant both are brought together at the same time, and in the same degree.

§ 4. **Landolt's Operation.**—Fig. 113 (B 1967).

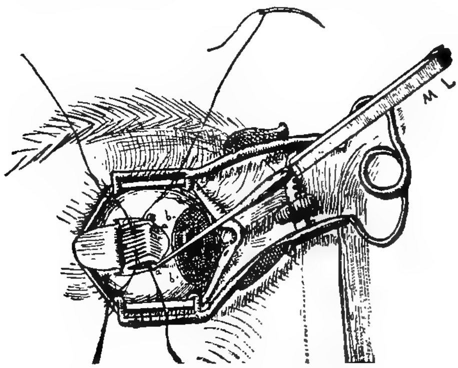

FIG. 113.—Landolt's operation.

The position and the form of the conjunctival flap are as shown in the figure. Making the muscle tense by rotating the globe, the fibers are caught up with forceps and a hook passed beneath the muscle. A black thread is introduced from without inwards, in the direction of the cornea, through the muscle and capsule, near its upper edge. Then it pierces the muscle a second time at the same distance from its upper edge, but nearer to the cornea. Another needle bearing a white thread is entered in a similar manner near the lower edge of the muscle. If a slight advancement only is desired, without resection, the needles pass inward above the hook; otherwise, below the hook. When the two ends of each suture are tied they of course fold the muscle upon itself. After the knot has been tied the projecting knuckle of the muscle is removed with the scissors.

§ 5. **Webster Fox's Operation.**—Figs. 114—115 (B 1965).

This is very similar to Critchett's operation. The conjunctival incision is an oval from above downward. Fox uses four sutures instead of three, and in doing so of course makes the position more secure. It has the advantage also over Critchett's operation, that when the conjunctival wound

is closed there is no puckering at the upper and lower edges.

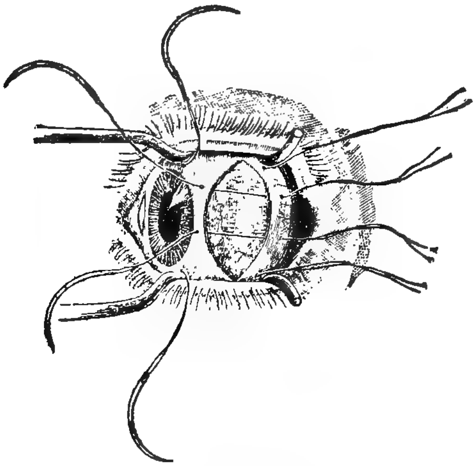

FIG. 114.—Webster Fox's operation.

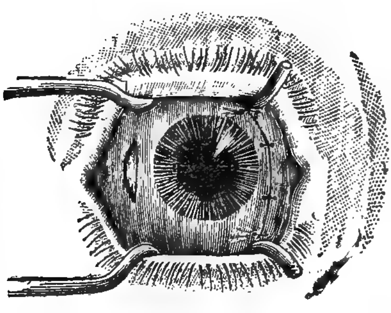

FIG. 115.—Webster Fox's operation. Sutures tied.

§ 6. **Verhoeff's Operation.**—Fig. 116 (B 1968).

The different stages are represented by the diagrammatic sketches, from one to five inclusive. It will be seen that anchorage is first obtained by passing a needle through the scleral tissue in a direction tangent to the cornea. Each needle then passes again through the same tissue in the direction of

the muscle for a few millimeters. In the third diagram the muscle is seen isolated, and held by the forceps. As each needle passes through the muscle, from within outwards, it pierces the tendon, transfixes not only "muscle but

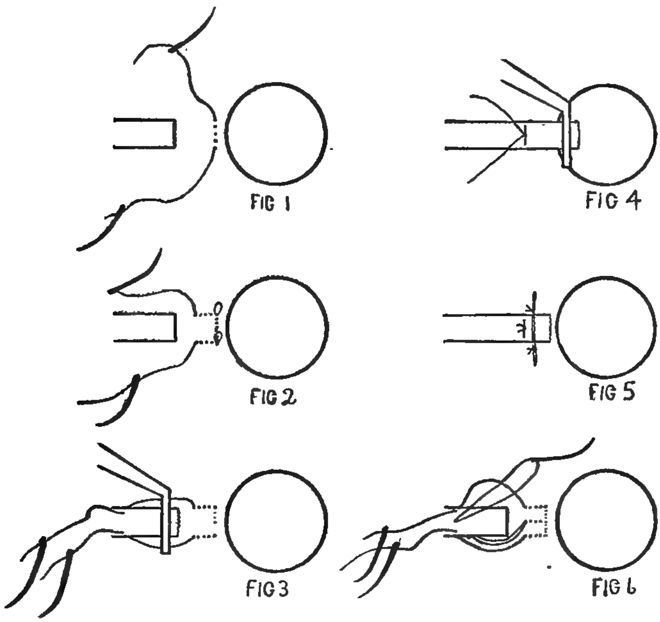

FIG. 116.—Verhoeff's operation.

capsule, and conjunctiva as far back as is necessary to obtain the desired effect." The divided muscle is then drawn forward as shown in the fourth diagram, and the wound closed as in the fifth diagram. For the sake of additional security it is sometimes advisable to introduce an additional thread as seen in the last diagram, but this is an unnecessary refinement of the procedure.

§ 7. **Worth's Operation.**—Fig. 117 (B 1970). Worth believes that much depends upon the character of the silk used. He prefers a thick black thread wound loosely around a piece of galvanized iron. The silk is boiled, carefully dried, and covered with a mixture of paraffine wax and vasoline.

In advancing a muscle he stands behind the patient, and having introduced the speculum he seizes the conjunctiva with toothed forceps, makes a vertical straight incision about half an inch long close to the cornea. With a similar incision he goes through the capsule. Having exposed the muscle, the perforated blade of a Prince's advancement forceps is passed under the tendon, and the forceps are closed, including between the branches tendon, capsule, and conjunctiva.

"One of the needles is then passed inward at A, through conjunctiva, capsule, and muscle, and brought out at the under side of the muscle. It is then again passed through muscle, capsule, and conjunctiva and brought out at B. The bight of the thread thus encloses about the lower fourth of the width of the muscle, together with its tendinous expansions and capsule and conjunctiva. The other needle is similarly entered at A′, passed through conjunctiva, capsule,

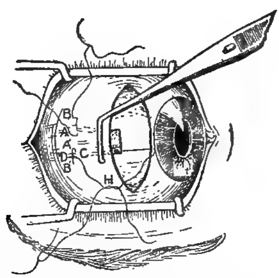

FIG. 117.—Worth's operation.

and muscle, and brought out at the under side of the muscle. It is then entered again at the under side of the muscle and brought out through the conjunctiva at B′, the bight of this suture thus inclosing the upper fourth of the width of the muscle, etc. The object of inserting both sutures before proceeding further with either is that they may be symmetrically placed. The ends of the thread from A′ and B′ are then knotted firmly at C. The end bearing the needle is then entered at D, and passed through conjunctiva, cap-

sule and muscle, and carried beneath the lower blade of the Prince's forceps nearly to the corneal margin. The needle is here passed through the tough circumcorneal fibrous tissue and brought out at G. The two ends of the thread are then temporarily tied loosely, with a single hitch, at H. The first suture is then similarly dealt with." When both sutures are in place, the two ends of each one are tied and the muscle with the adherent parts are drawn forward.

It is almost needless to add that there are several other procedures in this group. For example some operators, after resecting, reunite the divided tendon. Such modifications, however, are too numerous to mention.

CHAPTER III.

DIVISION III.

SUBDIVISION III.

Advancement Operations with a Pulley Stitch.

We are now to consider a third group of advancement operations. This is a small but important group. It does not separate itself from the others because of the tissue which is advanced, but by the manner in which the suture holds either the muscle alone or the muscle with its capsule in the new position.

In both of the former groups of operations the sutures passed from the muscle to their point of anchorage in the episcleral tissue or in some other portion of the muscle itself, and then the ends of the sutures were simply tied together. In the operations which we are now to consider another principle is involved. The suture passes from the muscle to its anchorage, and then, turning back on itself, is so arranged as to act as a pulley.

§ 1. **Prince's Operation.**—Figures 118 and 119 (B 1971).

First. After having made tenotomy of the opposing muscle, as is always his custom, he introduces a needle into the episcleral tissue at a point about four millimeters below the horizontal plane of the globe, and about one millimeter distant from the cornea. The needle follows somewhat the

curve of the cornea, and working little by little through the tissues it reaches a point about four millimeters above the horizontal plane, still at about a millimeter from the cornea. The stitch is drawn through, and the two ends of that suture allowed for the time to hang loose (Fig. 118).

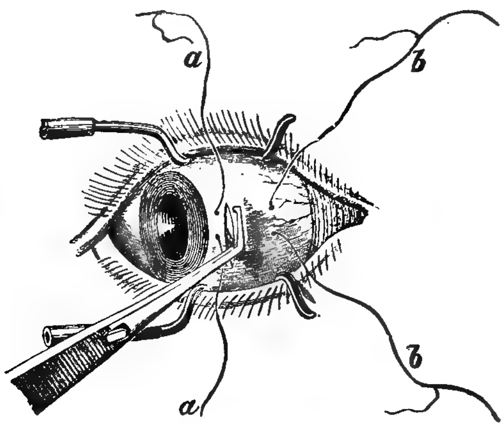

FIG. 118.—Prince's operation. First stage.

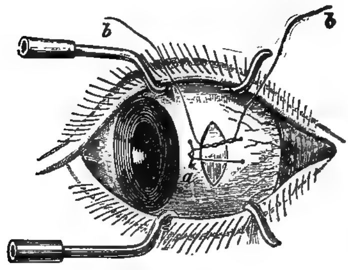

FIG. 119.—Prince's operation. Second stage.

Second. A fold of conjunctiva over the muscle is lifted up and divided across. One edge of the muscle is raised, and beneath it the surgeon passes one blade of a pair of clamp forceps. These are similar to those used by de Wecker, but stronger and better.

Third. The tendon is separated from the globe, the end of the muscle being still grasped by the forceps.

Fourth. A suture which has a needle at each end is selected, and one needle after the other is passed through the tendon and the overlying tissue from within outwards. The muscle having thus been firmly secured, the forceps are cut away with the part of the tendon which they grasped.

Fifth. One of the threads which project from the muscle is laid across the cornea, and the two ends of the first suture are tied firmly and closely down upon it (Fig. 119).

Sixth. The ends of the other suture are then tied. In doing this of course the muscle is drawn forward, and the amount of traction thus exerted determines the amount of correction made. Prince's operation was one of the first of this entire group, and had so many advantages that it soon became a favorite.

§ 2. **H. Lindo Ferguson's Operation.**—Fig. 120 (B 1972).

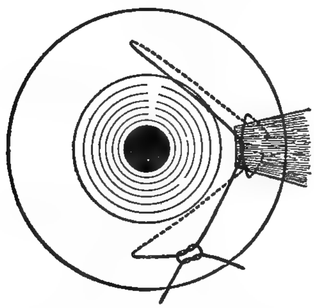

FIG. 120.—Lindo Ferguson's operation.

The conjunctiva is divided across the end of the muscle, the latter is isolated, grasped by the forceps, and divided close to its insertion. A silk thread having been armed with a small curved needle at each end, one needle is passed through the conjunctiva from without inwards near the cut edge, and at about the level of the upper part of the tendon as far back as seems necessary for the effect to be produced, then through the episcleral tissue above the cornea and out through the conjunctiva beyond the vertical meridian of the globe. The other needle is then passed through the conjunctiva at a lower level, through the lower part of the tendon and episcleral

tissue below the cornea, and out through the conjunctiva beyond the middle line of the globe. The upper needle is then slipped through the loop formed by the middle of the thread between the two points of entrances of the needles, and tied to the lower end, thus drawing the tendon and conjunctiva into place. The stitch has the same adjustable pulley action as Prince's; there is only one knot to tie, and only one thread to cut in removal. If the thread is cut between the knot and loop, it draws out with gentle traction on the knot.

§ 3. **Criticism on these Methods.**—Having examined thus several of the more usual methods of advancement, it is desirable at this point to inquire as to their advantages or disadvantages.

First: Comparing advancement of the muscle itself with advancement of the muscle and the capsule.

(*A*) The separation of the muscle from the capsule or adjacent tissue means a disturbance of the natural relation of parts which it is desirable to avoid.

(*B*) Advancement of the muscle alone is rather the more difficult, because of the more careful dissection necessary.

(*C*) As the sutures pass through, or are tied only to the fibers of the muscle itself, it is comparatively easy for the threads to cut through the fibers or to slip off from them.

(*D*) Advancement with the capsule is apt to produce more puckering of the tissues than advancement of the muscle alone.

On comparing these points, therefore, it appears that on the whole, advancement with the capsule is preferable.

Second: As to the arrangement of the suture. The pulley is as easily introduced as the other sutures, it can be tightened or loosened, and at the proper time the thread can be removed with comparative ease.

Third: One of the greatest difficulties in all these operations is that they require the anchorage to be made in what is usually described as the "episcleral tissue." This term has been used thus far without comment. But in reality the sutures are seldom or never in the "episcleral tissue" only. They are either in the conjunctiva, which is elastic and easily torn, or the needle enters the sclerotic

itself. That layer near the cornea is only about one millimeter thick.

The smallest needles are usually more than half a millimeter thick, including the curve, and with a good thread such a needle, near its eye, measures often .6 to .8 millimeter. If we use a larger needle it either does not penetrate the sclerotic, or if it does so, that is at the risk of passing through into the ciliary region.

The danger of attempting to anchor the stitches in the "episcleral tissue" was once impressed upon me by an accident which might occur to any one. The operator, at that time one of our leading colleagues in Berlin, was making an advancement, and on passing a small needle through this "episcleral tissue" the needle broke. The rough end of the part in the globe could be felt only as a point. It could not be extricated with the cilia forceps nor in any similar way. After many efforts it was necessary to abandon the original operation, to make an incision which opened the globe, and even then the fragment could be found only after careful search for a long time.

CHAPTER III.

DIVISION III.

SUBDIVISION IV.

Operation for Advancement with Anchorage to Adjacent Tendons—Procedure of the Author.

From the foregoing it would seem that the ideal operation for advancement would combine:

First, Advancement of the muscle with the capsule;

Second, A pulley suture; and

Third, Points of anchorage which are not in the scleral tissue.

Both of the operations of the last group have the first two of these desiderata. After several trials I have found that it is possible to add the third, and anchor the sutures not in the scleral tissue, but *to the tendon of the superior and inferior recti.*

At the risk of some repetition the following may be stated concerning this procedure.

§ 1. **Instruments.**—The speculum, toothed forceps, large hook, and scissors are the same as those already described. **The muscle clamp,** however, deserves a special word. The early form of this, as suggested by de Wecker, consisted simply of forceps bent near their ends at an angle. Later, Prince improved these, and placing a row of teeth on one branch, with corresponding perforations on the other, made them clasp the muscle with adjacent tissue much more firmly. These had the disadvantage, however, that being long and heavy, it was necessary to have them held by an assistant, or they fell to one side. In order to obviate this difficulty I had these forceps made much smaller and lighter, but very strong. In this way it is only necessary to attach them to the muscle, and they hold themselves in place (Fig. 121).

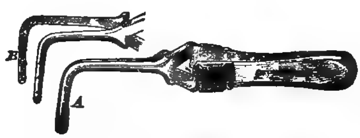

FIG. 121.—Short muscle clamp of the author for advancement.

Suture forceps. Another small but useful appliance is a pair of suture forceps (Fig. 122). This is nothing more than the cilia forceps with the opposing surfaces made large and rough instead of small and smooth. Two pairs are some-

FIG. 122.—Suture forceps of the author.

times convenient. After a suture has been passed we can reach down into the wound with such forceps and tighten

the ends of the thread much more satisfactorily than is otherwise possible.

V-shaped needles. In most cases the ordinary small curved needles are the most convenient. But every operator knows how difficult it is to introduce them satisfactorily when making certain operations on the orbit, especially on individuals whose eyes are unusually deep set. For example, in advancement of the internal rectus, with a considerable resection, it is not only dangerous but almost impossible to introduce the ordinary curved needle directly from without inward. A needle which has been found convenient is represented in Fig. 123.

FIG. 123.—V needle for the orbit.

In introducing it the muscle or tissue is drawn out, and the needle being grasped with needle forceps so that it extends straight out, its angle is thrust down into the orbit until the point of the needle is opposite the point where the thread is to enter. The muscle or other tissue is then bent over the point of the needle, or an assistant presses the tissue down upon its point with fixation forceps, and the needle enters up to its angle. When that is done the needle is turned entirely over, pushed farther through the tissue, and being grasped again, this time in the reverse direction, the thread is drawn through. Although the procedure is cumbersome at first, it becomes simple with a few trials. Such a needle permits us at least to introduce sutures in a position and in a direction which otherwise would not be possible.

Moreover, it is a practical necessity in the small operation which will be described later, as division of the muscle of Horner.

§ 2. Technique.

First. Having ascertained, as well as possible, from the arcs of rotation and other careful measurements, what is the condition of the muscle to be advanced, and also of its

opponent, a total or a simple tenotomy, as the case requires, is first made on the opposing muscle.

Second. A quadrilateral piece of conjunctiva is removed from over the tendon of the muscle to be advanced. The incision in conjunctiva and capsule is also extended a few millimeters backward along each border of the muscle.

Third. The muscle having been separated from the sclerotic by passing a hook beneath it, careful measurement is made with the millimeter hook (Fig. 87) of the amount to be resected in that case, that having been already determined.

Fourth. The perforated blade of the short advancement forceps is introduced beneath the muscle at a point which will allow resection of a proper amount, and the other blade

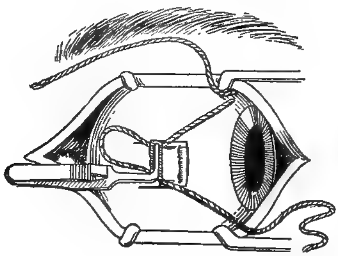

FIG. 124.—Author's operation. Early stage.

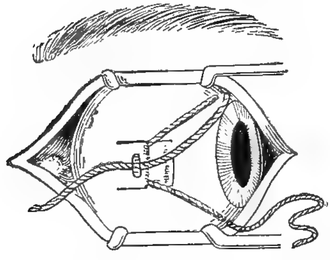

FIG. 125.—Author's operation. Later stage.

is made to clasp the conjunctiva, capsule, and adjacent tissue with the muscle.

Fifth. The tendon is divided close to its insertion, and the muscle turned back with the clamp.

Sixth. A long stout thread is armed at each end with a

small curved needle, or if the globe is deep set, with a V-shaped needle. One needle is passed from without inward near the upper edge of the muscle through conjunctiva, capsule, and muscle, and nearly half of the suture is drawn through. The same is done with the other needle. The muscle with adjacent tissue is then resected at the desired point.

Seventh. The upper needle is caught in the needle holder, and passed through the nearest edge of the tendon of the superior rectus muscle close to its insertion, together with the conjunctiva covering it. In a similar manner the lower needle transfixes the corresponding part of the tendon of the inferior rectus. These sutures are on the *outside* of the conjunctiva.

Eighth. The upper needle then retraces its course and passes through the loop of suture which was made over the muscle.

Ninth. The globe is now rotated toward the muscle to be advanced, the sutures are tightened gradually and equally, but firmly, as can be done with the aid of the suture forceps, and the ends brought together. It is convenient to have the knot thus below where it can be easily seen and tightened or loosened if desired.

In occasional cases, especially where the globe is set deep in the orbit, it is difficult or impracticable to make this pulley arrangement of the stitches. In one such instance in

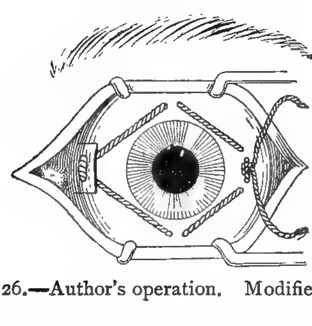

FIG. 126.—Author's operation. Modified form.

which advancement was made of the internal rectus it was found advisable to catch each suture through a small loop near the center of the tendon of the vertical rectus muscle,

then to continue it on the outside of the conjunctiva, pass it through the corresponding edge of the external rectus, and after rotating the globe well inward to tie the ends over the external rectus. A considerable reaction followed with a marked œdema, but the result was excellent.

Tenth. If a general anæsthetic has not been given, tests should be made to determine the degree to which the knot is to be tightened. Although previous measurements act as a guide, so that by estimating five degrees for each millimeter we are able to place the muscle approximately in the position which it should occupy, still, the real position of the globe is shown by objective, and especially by subjective tests.

Therefore, all that has been said of the importance of such tests for tenotomies holds equally true for advancements in any form. When diplopia is present or can be elicited these tests are comparatively simple. When diplopia is absent, no pains should be spared to make the objective measurements as complete as possible. It is of course extremely annoying to the patient to keep marching back and forth from the chair or table to the dark room—though this is obviated if the operating room can be darkened. But as a slight change in the position of the muscle may make a great difference in the result, the importance of these tests in all such operations is evident. The habit of hurrying to finish and leaving such measurements until it is difficult or impossible to correct any errors, is perhaps the most frequent cause of unsatisfactory results.

Eleventh. After the muscle is brought to the position desired, the redundant tissue over the wound is snipped off, or if necessary a fine superficial stitch is introduced to keep the conjunctiva in place.

§ 3. **The After-treatment Is Important.**—Both eyes should be bandaged till near the end of the first week; careful antisepsis followed; atropin used if ciliary injection develops or anodynes given if pain is severe. Almost any time after the first week the sutures come away or can then be removed, and from that point the injection rapidly subsides.

CHAPTER IV.

OPERATIONS ON THE VERTICAL MUSCLES.

§ 1. **Tenotomy of the Vertical Muscles.**—We have already seen that the vertical latent deviations are apt to give rise to more annoying symptoms than the corresponding degrees of horizontal latent deviations. Therefore the question of making some operation for the correction of the former may arise even more frequently than with regard to the latter; moreover, vertical actual deviations, though relatively rare, sometimes demand operative treatment.

It is unnecessary, however, to repeat what has been said concerning the indications for, or the technique of partial, or simple, or total tenotomy. These are the same for the vertical as for the horizontal muscle. In dealing with the vertical muscle, however, it should be borne in mind:

(*A*) That the field of operation is small and every manipulation proportionately difficult.

(*B*) In any operation made upon the inferior rectus care should be exercised not to interfere with the inferior oblique. We should remember that these two muscles are so joined by bands of connective tissue that a disturbance of one is apt to affect the other, at least enough to give rise to complicating symptoms.

§ 2. **Advancement of the Vertical Muscles.**—The indications for this and the technique are also practically the same as for advancement of the horizontal muscles. As most of these vertical deviations are in a comparatively slight degree, when different tests indicate that a deviation is essentially of a passive character, or of such a composite type as to demand advancement, usually some form of the tucking operation is sufficient.

CHAPTER V.

CHOICE BETWEEN TENOTOMY AND ADVANCEMENT.

When glancing at the history of operations on the ocular muscles, we found that although we have learned something concerning them during the last half century, there is still great diversity of opinion as to when one muscle should be lengthened or its opponent shortened. Of late years, one or two of our best operators have stated in substance that tenotomy should never be made. It is taken for granted by them that every deviation is caused more by relaxation of one muscle or group of muscles than by contraction of the opponent. With such a premise, it is natural to conclude that to lengthen one muscle is simply to make a bad matter worse.

There is, however, one very simple but important fact which shows that such a broad generalization is not warrantable. This fact is that hundreds of tenotomies have been made and are constantly being made upon deviating eyes, with practically perfect results. Indeed, some operators, being satisfied with tenotomies, do not attempt advancements except for evident paralyses, or, after having made advancement as a routine practice, return to tenotomies.

Concerning this question there are, however, a few propositions on which we probably all agree.

(1) In all deviations of the purely passive type (evident paralysis) of one muscle or group of muscles, advancement in some form is the only operation to be considered.

(2) In deviations of a composite type, advancement is preferable, although improvement may also be obtained by tenotomy.

(3) In deviations of an active type, especially if of the

active hypermetropic kind so frequently found with esotropia of early life, some form of a tenotomy, on one eye or both, often gives excellent results both as to position and binocular vision.

(4) Advancement is more painful and tedious than tenotomy. The visual axis can be turned into the desired position much more easily and promptly by a carefully graduated tenotomy of some form than by tightening or loosening a stitch after an operation for advancement.

(5) Advancement sometimes leaves a perceptible scar. A tuck especially is visible as such, at first, and the spot may persist for months, an annoyance to the patient and a discredit to the surgeon.

(6) The effect produced by advancement, especially in cases of esotropia, is not always sufficient—a fact which was recognized clearly by Landolt himself. He says: "If, in spite of everything, the patient continues to squint, there is always time to add a tenotomy to our two advancements."

In a word, therefore, when we ask ourselves in a given case whether it is best to make tenotomy or an advancement, the answer must depend mainly on our diagnosis of the form of the deviation presented. If the personal experience of over thirty years may be cited, on reviewing my own unfavorable results, especially those of earlier years, I am convinced that usually the fault has not been in the manner in which the operations were made, but in the diagnosis, and therefore in not selecting the right operation for the right case.

CHAPTER VI.

ACCIDENTS AND DEFORMITIES FROM OPERATIONS.

§ 1. **Accidents** which may occur are

(*A*) **Perforation of the Sclerotic.**—This membrane may be perforated by a needle or by the scissors.

A needle will appear at first to make no progress, and then suddenly emerge considerably beyond where it is expected to appear. Such needles are usually dull or dirty, and, if there is the suspicion of either, they should be thrown away. Another accident consists in the puncture of the sclera by the scissors. A number of such instances have been reported. Fortunately, however, when these wounds are closed by drawing the tissues together and treating them on strict antiseptic principles, they heal promptly.

(*B*) **Hemorrhage.**—Not infrequently considerable bleeding occurs beneath the conjunctiva, lifting it up and producing extensive ecchymosis. When this occurs it is a good plan to incise the tissues freely, or, if the bleeding vessel is found, to twist or tie it. With hæmophiles, this complication is sometimes quite annoying. I have seen the entire conjunctiva lifted up by hemorrhage and become black and firm within a few minutes. The application of a tight roller bandage causes the swelling to subside, but the ecchymosis may extend to the lids and last for weeks, much to the discomfort of the patient.

(*C*) **Circumscribed cellulitis** is not uncommon. In spite of all our efforts to keep the wound entirely clean, localized infection occasionally occurs, accompanied by œdema of the conjunctiva, or even a circumscribed cellulitis.

Ordinarily, however, the removal of the stitch rather earlier than usual, and the application of antiseptic washes

are sufficient to bring this under control. A more serious complication is:

(*D*) **Orbital cellulitis.**—Fortunately these cases are exceedingly rare, though a few which are quite typical occur in the literature.

§ 2. **Deformities and Liability for them.**—In certain rare cases the combination of circumstances may be such that when even the most skilful surgeon attempts an apparently simple operation, a deformity may result greater than that which originally existed. A question might then arise as to what liability, if any, is incurred.

It would be far beyond the limits of a study like this to consider questions which belong to legal medicine, but it is proper to call attention to a decision recently given by the United States Court of Appeals, Eighth Circuit, in the case of the Southern Pacific Company against Hetzer. The ruling of the Court was to the effect that the deformity, as such, was not a matter for which damages could be estimated, and therefore adjudged. In most cases where an original deformity is increased, or when it is produced *de novo* by operations on the ocular muscles, that result is due to the carelessness of the patient. These occur most frequently among the ignorant patients, and are usually clear cases of contributory negligence. In any event, if no fee has been paid or charged—as, for example, for a charity case at a hospital or dispensary—then in most of our states there is no liability on the part of the surgeon or of the institution.

CHAPTER VII.

DIVISION OF THE MUSCLE OF HORNER

FOR ADVANCEMENT OF THE CARUNCLE

Even in the early days of tenotomy of the internal rectus, attention was called to the disadvantage of the sinking of the caruncle. This resulted not only in a deformity, but in some individuals the position of the globe was such as to interfere with the proper escape of the tears. Many attempts, therefore, have been made to obviate this difficulty, notably by Liebreich and others, but our best efforts still too often result unsatisfactorily.

If, however, we glance at the anatomy of the region of the caruncle, a solution of this problem is suggested. The difficulty seems to lie, to a considerable extent at least, with the muscle of Horner, to which our attention has already been called.

This muscle is probably what remains of the nictitating membrane, and an unfortunate legacy it is to persons on whose eyes it becomes necessary to make a tenotomy of the internal rectus. We have seen that these microscopic bands, arising just behind the crista lacrymalis, pass forward and outward almost horizontally, to be inserted into the caruncle and into the connective tissue, covering the median surface of the internal rectus. Of course they tend to draw the caruncle medianwards.

The idea of transplanting the caruncle is by no means new. It was proposed long ago, but the lack of anatomical data left earlier operators ignorant of the rationale of the procedure. The first suggestion was simply that the base of the caruncle be separated from the inner wall of the orbit, no care being taken as to the depth or form or size of the

incision, and especially no precaution to prevent the reattachment of the tissues in the same place.

It is not difficult to do this properly, although the technique requires some care.

Cocain having been instilled and the speculum introduced, the caruncle is seized with a pair of strong forceps and drawn outward as far as possible. This is usually attended with considerable pain, and patients who will bear a tenotomy or a tedious advancement without a murmur, often complain bitterly or even require a general anæsthetic when traction is made on the caruncle. The operator, taking a cataract knife, partly circumscribes the caruncle with an incision which is convex medianwards, and has each end extending parallel to the canaliculi and approximately of their length. He then carefully dissects the caruncle from its attachment to the outer wall of the lacrimal sac, being sure not to wound the sac, and of course not to divide either the upper or lower canaliculus. The bleeding, although not profuse, is often annoying, as it is necessary for the operator to see his way clearly at each step. He gradually advances the incision into the orbit to a depth of five to six millimeters over the lacrimal sac, though from that point it gradually grows more shallow along the line of the upper and lower lid.

Next to the incision, the most important point is to introduce the stitches in such a manner as to prevent the wound from reuniting in its original position.

In earlier trials with this operation it was done only as an accompaniment of tenotomy of the internal rectus, and in those cases I was accustomed, after dividing the insertion of the tendon, to draw the conjunctival wound together by passing the needle first through the fragment of conjunctiva which was left near the edge of the cornea, then through the conjunctiva over the muscle, including in that thread even a part of the superficial connective tissue. Then, as the semilunar fold, together with the caruncle, was drawn forward, the latter, having been already loosened by the incision just described, was easily transplanted, so to speak, upon the globe. In many cases this simple procedure is quite sufficient, particularly if the bandage is removed rather

sooner than usual and the patient allowed to move the eye freely.

More recently, however, I have found that a better result could often be obtained by drawing together the conjunctiva as much as possible *from above downwards*, over the space between the orbital and ocular surfaces. This is more easily said than done. Even the shortest needles with the ordinary curve are quite useless for closing properly such a small deep pocket. For that purpose the small "V" needles, already described, are convenient. One of these is introduced from without inwards into the conjunctiva, at a point corresponding to what was the lower edge of the caruncle, and the thread drawn through. The edges of the wound are then drawn apart, the "V" needle is pushed well down into it and inserted, from within outwards, at a point corresponding to what was the upper edge of the caruncle. This prevents the caruncle from slipping back to its original position as the wound heals.

CHAPTER VIII.

DIVISION OF THE ACCESSORY MUSCLES.

In an earlier part of this study, our consideration of the accessory muscles of accommodation led to the conclusion that their prolonged and forcible contraction was one of the causes of ocular headache. In the vast majority of cases, of course, this headache can be relieved by re-establishing the muscle balance.

But occasionally the headache persists in spite of everything, and careful study shows that it is due largely, if not entirely, to an excessive action of the accessory muscles of accommodation.

The indications for operative interference in these cases are :

First, severe and almost constant frontal headache, which can not be relieved by the most exact correction of any existing ametropia, the absence of any other form of muscle imbalance, and the fact, shown by accurate tests, that the headaches are not dependent on any gastric, renal, or other so-called general cause.

Second, the wrinkling of the forehead in the form of a scowl. When efforts at accommodation are excessive or long continued, these wrinkles are usually of the vertical type, indicating that the corrugator supercilii is also at fault, but they may also be largely of the horizontal type.

Third, an increase of this headache when efforts at accommodation are increased, or even when slight efforts are continued for a long time.

Fourth, a decrease of the headache when these efforts are decreased, or its absence when the accommodation is entirely relaxed by a cycloplegic.

With such a condition, when every possible effort has been made with glasses and otherwise to restore the muscle balance, and to establish a perfect condition of the general system, as a last resort, I have made in a few cases, a myotomy especially of the anterior fibers of the occipito-frontalis.

While this operation is simple enough in itself, the annoyance always experienced from hemorrhage and the desirability of avoiding a disfiguring scar call for a few words concerning it. The most desirable place in which to make the incision is along the line of the eyebrow. Accordingly the first step is to shave off each eyebrow and disinfect the surface thoroughly. In order not to have this incision any longer than possible, especially over the root of the nose, it is convenient to use a knife with which a subcutaneous incision can be made easily and at the same time thoroughly. At first an attempt was made to extend the incision laterally beneath the skin by pushing across the fibers of the muscle a grooved director, and following this with a curved bistoury. That was found cumbersome, however, and after several trials a small bistoury protected with a sheath, such as is seen in Fig. 127, was used.

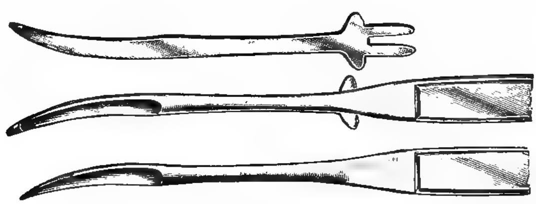

FIG. 127.—Protected bistoury, for dividing the fibers of the occipito-frontalis.

An incision is made from the inner margin of the brow up and outward, following its curve to its center. As soon as this incision is extended to the periosteum, we meet not only the branches of the supraorbital artery, but other small vessels in that vicinity, which always cause an annoying flow of blood. If the ordinary hæmostatic forceps are used, the wound soon becomes cumbered, and the progress of the operation interrupted. It is much better to use strong but

fine short hæmostatic forceps, not more than twenty or thirty millimeters in length. As soon as the hemorrhage from the supraorbital is arrested, the incision can be extended outward along the line of the brow almost to its outer margin, and quite down to the periosteum. As the fibers of the occipito-frontalis which pass upward near the root of the nose are often the strongest and are re-enforced by fibers of the corrugator supercilii, it is desirable of course to divide these also. But an extension of the wound from one brow to the other would be apt to leave an unsightly scar. In order to obviate this the operator seizes the skin over the root of the nose between his left thumb and index finger, and pinching it together firmly, lifts it from the underlying tissue. Then taking the protected bistoury, already described, in his right hand, the covered point is thrust beneath the skin from the median end of one incision straight across until it appears in the incision over the other eyebrow. After disengaging the sheath which covers the point, the latter is turned toward the skull, dividing the fibers which lie just beneath the skin. This part of the operation also is followed by annoying hemorrhage, but with patience it can be controlled, pressure over the surface being of decided advantage. After the bleeding has stopped sufficiently to permit the wound to be properly cleaned, the edges are brought together by three or four sutures, preferably of catgut (Fig. 128).

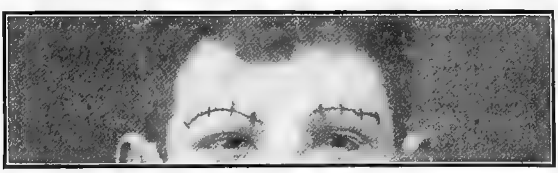

FIG. 128.—Line of incision of the anterior fibers of the occipito-frontalis.

The immediate results of this operation seemed quite satisfactory in the few cases in which it has appeared warrantable. But a sufficient time has not yet elapsed, in some of these instances, to speak with confidence concerning the

ultimate results. Moreover, the lessening or entire disappearance of the frontal headaches may not be due as much to the division of the muscle fibers as to the section of the supra-orbital nerves.

Finally it should be mentioned that in one case in this series a very disagreeable feeling of numbness of the forehead continued for several weeks after the operation. Taken all together, however, this procedure, in a certain small class of cases, seems to be of real value.

CHAPTER IX.

CONCLUSIONS.

In the last chapter of the first volume a recapitulation was made of the salient points to which attention had been directed, and from them a few conclusions were drawn. In this volume, as the course pursued was somewhat different from that followed by former students in the same field, it seemed advisable for the sake of clearness to halt occasionally for a brief review. It is therefore unnecessary now to repeat each of those short summaries, but we may ask what general conclusions can be drawn from the facts observed. These conclusions might be almost innumerable if carried into detail. It is better, therefore, to attempt to state only a few of the more important. Beginning with the lesser variations from the normal condition we find:

As ocular muscle balance must be the standard for comparison, muscle imbalance must always be measured by that normal standard.

In muscle imbalance as this is usually understood, an instinctive effort is made to obtain or to maintain binocular vision. This often results in "eye-strain," or in "asthenopic symptoms."

The condition of imbalance itself should not be confused with its results, such as eye-strain, asthenopia, etc.

In the examination of cases of imbalance a certain definite plan should be followed, and the data obtained recorded in an accurate, systematic manner.

In every case of imbalance we should ascertain as nearly as possible what group of muscles is affected, and whether their action is excessive or insufficient.

We should remember that this excessive or insufficient

action may be *actual*, as measured by the normal standard, or only *relative*, as compared with the *resistance* to be overcome by that group of muscles in that eye.

In every case where practicable it adds to clearness to construct a diagram, mentally or actually, in order to see the character and the degree of the abnormal action of each group of muscles, and the resistance offered to them.

It is impossible to make a complete examination of any case of imbalance at a single ordinary visit, and in the usual routine of office work it is only practicable to observe the more salient points and arrive at a *provisional* diagnosis.

When only one group of muscles with the resistance offered to them is affected, we can conveniently consider these as cases of *simple* imbalance, as distinguished from *compound* imbalance, when two or more groups of muscles with the resistance offered to them are affected.

Imbalance involving the intraocular muscles (heterocykinesis) constitutes the most important group with which we have to deal, and the tests for these anomalies of accommodation require more time and care than any other.

Imbalance involving the extraocular muscles (heterophoria), although readily recognized, also frequently demands careful study. Without a complete knowledge of the kind and degree of the imbalance in a given case, it is impossible to arrive at a final diagnosis.

Esophoria seldom gives much annoyance and requires comparatively little treatment.

Exophoria is frequently accompanied by annoying symptoms. Its treatment by any of the methods thus far at our command is not always satisfactory, and frequently demands attention to many details.

Excessive and insufficient torsion cannot always be recognized satisfactorily. We have still much to learn concerning them, especially as to the effects which cylindrical glasses may produce in their correction.

Latent deviations of the vertical muscles are undoubtedly quite common and of some importance, but that is often overestimated.

While compound imbalance is the form ordinarily met

with, its intelligent treatment requires that the factors present in the individual case be clearly separated from each other, the importance of each distinctly measured, and a mental or actual diagram made of each, in its relation to the others.

The ocular muscles produce certain distinct effects on the eye itself, on neighboring structures, and indirectly on different parts of the body.

The intraocular muscles may affect the structure of the iris, the choroid, and possibly the retina or the optic nerve.

The extraocular muscles affect the curvature of the cornea and the intraocular tension.

The intra- with the extraocular muscles may produce hyperæmia of the conjunctiva, increased lacrimation, blepharitis, and by the direct action of the associated muscles of accommodation may cause one form of headache.

The ocular muscles may also affect other parts of the body, primarily the nervous system, this reflex showing itself as another form of headache, or as a general fatigue, neurasthenia, hysteria, or possibly chorea, epilepsy, or other nervous disturbance.

The ocular muscles also have apparently some effect upon the secretion of the stomach or other organs of the body, but these effects are by no means well defined, and their frequency and importance are often grossly exaggerated.

As the ocular muscles affect other portions of the body, so the latter may affect the eyes. We may have only the symptoms of imbalance, such as result, for example, from a simple conjunctivitis, or headaches, which are of a purely reflex character. On the other hand, certain disturbances of digestion or of nutrition occasionally do produce not only the symptoms of imbalance, but actual conditions of imbalance which can be measured by prisms or other appropriate tests.

In the local treatment of imbalance with glasses our prescriptions should be sufficiently explicit to enable the optician to furnish the glasses which are desired.

Although glasses may be supplied which afford relief from annoying symptoms of imbalance, in any examination

limited to the local conditions, the knowledge of the case is necessarily restricted, and the treatment therefore proportionately imperfect.

An intelligent general treatment of imbalance frequently necessitates tests of the blood, the urine, or of the stomach contents, or examinations of the condition of other organs or parts of the body which may be at fault, and careful treatment by the most modern and improved methods.

Among the methods of general treatment, simple forms of gymnastic exercises often occupy an important place.

Actual deviations should be measured accurately, objectively and subjectively, and a record made as to the amount of the deviation and its position; if practicable, we should learn the lifting power of the adductors or even occasionally make a photogram of the arc of rotation.

The actual (apparent) deviations, like the latent, are due to excessive or insufficient action of the extraocular muscles. In these deviations, however, there is ordinarily no instinctive effort to obtain or maintain binocular vision, and no evidences of "eye-strain" or of "asthenopic symptoms."

As every deviation is only a symptom, we should ask ourselves where the lesion is, of what it consists, and why it produces that form of deviation in that case.

Lesions situated in the muscles themselves or in the globe are those which are apt to produce the non-paralytic or active deviations.

Deviations due to abnormal conditions of the muscles themselves have not been studied with the care which they apparently deserve.

Hypermetropic esotropia in its pure type is comparatively rare, but when it exists it can often be satisfactorily treated with glasses alone.

Myopic exotropia is less amenable to any treatment.

Deviations with imperfections of the retina are seldom of a pure type, and their non-operative treatment, though tedious, is advisable whenever practicable.

Deviations are usually in the horizontal plane, apparently because the horizontal muscles are larger and stronger than the vertical.

As the compound forms of active deviations are the most common, it is essential in each case to determine what the lesion or lesions are, and what is the relative importance of each in that individual case.

Lesions situated in the brain or in the nerves are those which produce the paralytic or passive deviations.

We know comparatively little of these lesions, because although we have innumerable cases of that kind on record, the instances are comparatively few in which microscopic examinations have also been made of the lesion according to modern methods.

In such cases it is desirable to study carefully the objective and subjective symptoms, and to locate the paralyzed muscles.

Much work still remains to be done in ascertaining definitely the cause of these paralyses, as a basis for more intelligent treatment.

Atypical movements of the eye, especially forms of nystagmus, also call for more careful study, but the correction of refractive errors is too often neglected, because unusually difficult.

Some operations on the ocular muscles demand as much care and exactness for their proper execution as operations on the iris or lens.

Partial tenotomy is not only possible, but when conservatively and intelligently used, has a well defined place in ophthalmic surgery.

In simple tenotomy delicate instruments must be used with the utmost care in order to obtain the best results.

In total tenotomy no such exactness is necessary, in the instruments or the manner of their use.

In all operations for tenotomy it is far better to do too little than too much.

Tucking operations, when properly executed in selected cases, are in general satisfactory, in spite of the temporary deformity which the tuck produces.

Among the multitude of operations which have been proposed for advancement, it is difficult to single out any one which is pre-eminently the best. Experience indicates, how-

ever, that the ideal operation consists in the advancement of the muscle with its capsule or adjacent tissue, in arranging the sutures so that they act as a pulley, and in making the anchorage not in the scleral tissue, but to the tendons of adjacent muscles. These objects seem to be accomplished by the advancement operation, which is described last in the list.

The question whether to make tenotomy or advancement in a given case depends upon the character of the deviation.

Advancement is always indicated for a typical passive deviation, usually for a composite deviation, and it is possible to produce improvement with it in an actual deviation.

Tenotomy, however, is much the simpler operation. It is specially indicated for all active deviations, and the good results constantly obtained with it in this class of cases, and sometimes in cases of the composite type, cause tenotomy to hold its place in spite of theoretical objections.

Sinking of the caruncle can be lessened by division of the muscle of Horner.

In certain selected cases where headaches are evidently dependent upon excessive action of the accessory muscles of accommodation, at least temporary improvement can be obtained by section of the anterior fibers of the occipito-frontalis.

Many of these problems concerning the pathology and treatment still remain unsolved, and some future student will write a much more complete and satisfactory treatise on the ocular muscles than is possible now.

APPENDIX A.

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INDEX OF THE AUTHORS REFERRED TO IN THE BIBLIOGRAPHY

APPENDIX B.

SUBJECTS FOR STUDY.

The reasons for this list of questions are given in the first volume, page 435.

QUESTIONS

What is the frequency of actual excessive or of actual insufficient accommodation or convergence, as shown by accurate measurements?

What central lesions or toxæmias produce actual excessive accommodation or actual excessive convergence?

In a considerable number of cases of heterophoria what is the form of the photogram, and does this vary in proportion to the degree and form of the imbalance?

What additional facts are there which point to a relation between the occipito-frontalis or the corrugator supercilii and frontal headaches?

To what extent are horizontal wrinkles on the forehead abnormally abundant in the vertical phorias?

What relation, if any, do anomalies of the vertical muscles bear to anomalies of accommodation, convergence, or torsion?

What are the ultimate causes of other forms of heterophoria?

What reliable measurements have we to show the frequency of anomalies of torsion?

What is the relation of torsion to convergence in hypermetropia or in myopia?

What percentage of uncorrected astigmatics tip the head? If any, why not all?

Is there any relation between the direction of the tipping of the head and the axis of the astigmatism?

What family histories can be collected to show the influence of heredity in the production of (*a*) esophoria, (*b*) exophoria, (*c*) hyperphoria, (*d*) hypophoria, (*e*) cyclophoria?

Does excessive accommodation ever produce peripheral opacities of the lens?

Exactly what effects do the intraocular muscles produce on, (*a*) the iris? (*b*) The choroid? (*c*) The retina? (*d*) On any other part of the globe?

What abnormal conditions of the extraocular muscles are associated with astigmatism in different meridians?

Is inflammation of the cornea influenced by pressure of the extraocular muscles upon the globe? If so, in what corneal diseases?

How can muscle imbalance produce conjunctivitis?—or blepharitis?

Is there any relation between astigmatism against the rule and exophoria?

What lesions in the eyes, but not involving the muscles, also produce symptoms of imbalance?

Demonstrate the fibers of the sympathetic nerve which connect the eye with the cervical ganglia, and show their pathological relations.

Is any special variety of headache referable to the forehead, to the vertex, or to the occiput ordinarily associated with a special variety of heterophoria?

What further evidence is there which indicates a relation between imbalance and (*a*) neurasthenia, (*b*) hysteria, (*c*) chorea, (*d*) epilepsy, (*e*) or other nervous conditions?

What reliable evidence is there which indicates a relation between the ocular muscles and (*a*) the stomach, (*b*) any other portions of the digestive tract?

Are there any special gastric symptoms which are ordinarily associated with any special form of heterophoria?

Among persons who seldom or never have the so-called "panorama" headaches what percentage do have ocular imbalance?

What toxæmias produce symptoms of imbalance?

What other morbid conditions not in the eyes, and also not in the muscles, do produce symptoms of imbalance?

Is there any relation between eyestrain and the amount of the blood pressure?

Is there any way in which to determine how long an assisting prism should be worn before its position is reversed?

When heterophoria or heterotropia has existed what is the post mortem condition of the ocular muscles?

What additional evidence can be furnished by postmortem examinations to show that heterotropia is or is not dependent upon the abnormal size or abnormal insertions of the recti muscles?

In a considerable number of eyes in which heterotropia exists, what position do the axes assume in natural sleep? In narcosis? After death?

Does the correction of ametropia in early childhood lessen an actual deviation by relaxing the accommodation or by improving the retinal image or both?

In a considerable number of cases of simple or compound hypermetropic esotropia in children, what proportion of the axes became "straight" without the use of corrective glasses, as compared with those who did wear them?

What are the unusual conditions which produce esotropia in a myope, or exotropia in a hypermetrope?

In such cases, what does postmortem examination show concerning the condition of the lateral recti and their insertion?

Why are lateral forms of heterotropia more common than the vertical forms?

In a series of cases of heterotropia what are the different factors which produce deviation in certain directions?

In a considerable number of cases of paralysis of the motor oculi, in what proportion are one or more branches supplying the external muscles affected as compared with those in which the paralysis is complete?

In a considerable number of cases of paralysis of the motor oculi, which of the external branches are usually affected first, and what is the sequence of the appearance of the paralysis?

In a considerable number of cases of paralysis of any of the ocular muscles, what are the most frequent causes and what are the terminations of these cases?

If we know the lifting power of the adductors before a tenotomy is made, what is the lifting power when the insertion of the muscle is displaced backward a given number of millimeters?

What is the relative importance of the different factors which influence precision in operations on the recti?

What is the best method of making simple tenotomy, and why?

What form of tenotomy of the internal rectus prevents most effectually the sinking of the caruncle?

What is the best method of making advancement, and why?

What new data can be obtained to help us in deciding when to make tenotomy, or when advancement?

APPENDIX C.

OPHTHALMOLOGICAL JOURNALS IN CERTAIN ENGLISH LIBRARIES.

The introductory note to Appendix C in the first volume gave the reasons for attempting to show where ophthalmological journals can be found in certain American libraries. The tables in that volume were designed to facilitate the efforts of students to consult libraries in their own vicinity.

In the United Kingdom, however, these large institutions are nearer to each other than in America. Therefore the list of such libraries need not be so large. Moreover, in certain localities—Edinburgh, for example—the most complete files of ophthalmological journals are in private libraries. It is hoped, however, that the following short list may prove of some use to students of this or other branches of ophthalmology in England.

LIST OF PERIODICALS.	First Vol. Published in
1. American Journal of Ophthalmology	1884
2. Anales de Oftalmologia (Mexico)	1900
3. Annales d'Oculistique	1838*
4. Annali di Ottalmologia	1871
5. Annals of Ophthalmology	1892
6. Archives d'Ophtalmologie	1853
7. Archives of Ophthalmology	1869
8. Archivio di Ottal. (Palermo)	1893
9. Beiträge zur Augenheilkunde	1895
10. Bericht der Ophthal. Gesellschaft in Heidelberg	1863
11. Bolletino d'Oculistica (Firenze)	1870
12. Bulletin Société Française d'Ophtalmologie	1883
13. Centralblatt für praktische Augenheilkunde	1877
14. Clinica Oculistica	1900
15. Clinique Ophtalmologique	1895
16. Graefe's Archiv für Ophthalmologie	1854
17. Klinische Monatsblätter für Augenheilkunde	1863
18. Nagel's Jahresbericht der Ophthalmologie	1870
19. Nederl. Tijdsch. v. Geneeskunde	1857
20. Ophthalmic Record	1891
21. Ophthalmic Review	1881
22. Ophthalmic Year Book	1904
23. Ophthalmologische Klinik	1897
24. Ophthalmology	1904
25. Ophthalmoscope, The	1894
26. Proceedings Western Ophthal. and Otolog. Association	1897
27. Recueil d'Ophtalmologie	1873
28. Reports Royal Lond. Ophthal. Hospital	1857
29. Revue Général d'Ophtalmologie	1882
30. Trans. Internat. Ophthal. Congress	1857
31. Trans. of the American Ophthalmological Society	1865
32. Trans. Ophthal. Society of the United Kingdom	1880
33. Trans. Section Ophthal. American Medical Assoc.	1891
34. Wochenschr. für Ther. u. Hyg. des Auges	1897
35. Zeitschrift für Augenheilkunde	1899

* 2 vols. a year.

	BRADFORD. Eye and Ear Hospital.			BRISTOL. University College.			EDINBURGH. Royal Coll. of Surgeons.		
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	LONDON. Ophthal. Society.			LONDON. Royal Coll. Surg. Eng.			MANCHESTER. Medical Society.		
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INDEX OF AUTHORS.

INDEX OF SUBJECTS

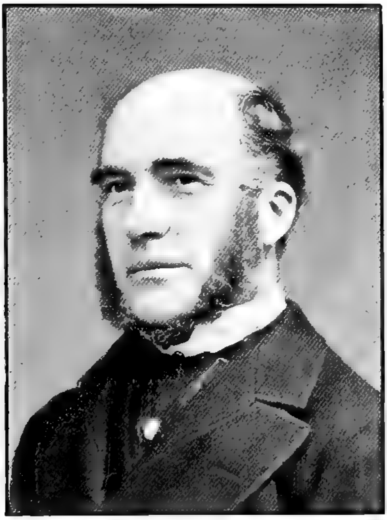
BIOGRAPHIC NOTES

OF A FEW EMINENT STUDENTS OF THE OCULAR MUSCLES.

The reasons for these notes are given in the first volume, page 457.

Graefe, Albrecht von. The great ophthalmic clinician. Born May 22, 1828. Studied at Berlin, later at Prague under Arlt. Returned to Berlin in 1850. Published his monograph on the ocular muscles in 1852, Physiology and pathology of the obliques, 1854. Many other important articles on the muscles were published in the *Archives of Ophthalmology* which he founded. Accomplished perhaps more than any other practitioner to advance our clinical knowledge of the muscles. Died July 20, 1870.

DIEFFENBACH, JOHANN FRIEDRICH. Born in Königsberg, 1795. Studied theology first, afterwards medicine. Became one of the most prominent surgeons in Berlin. Was the first to make tenotomy of the internal rectus for the cure of convergent strabismus. Died Nov. 12, 1847.



CRITCHETT, GEORGE. Born in Highgate, England, in 1818. Member of the Royal College of Surgeons in 1839, and Fellow in 1844. For many years surgeon at the Royal London Ophthalmic Hospital, and consulting ophthalmic surgeon at other London hospitals. Was the first to make subconjunctival tenotomy, and one of the first to systematize a method for advancement with the adjacent tissues. A clinician of an unusually large experience, especially interested in the surgery of the ocular muscles. Died Nov. 1, 1882.

MAUTHNER, LUDWIG. Born April 13, 1840. A student of von Jaeger. Professor of Ophthalmology at Innsbruck, 1869 to 1877. In 1894 was appointed successor of Stellwag at Vienna. His works on the *Testing of the Functions of the Eye* (1880), *On the Brain and the Eye* (1881), and especially his *Lectures on the Ocular Paralyses* place him among the most prominent contributors to this branch of pathology. Died 1894.

NOYES, HENRY D. Born in New York City in 1831. College of Physicians and Surgeons, 1855. A Student of von Graefe. Surgeon New York Eye and Ear Infirmary from 1864 till his death. For several years President of the American Ophthalmological Society. Author of a voluminous text-book on diseases of the eye. Appreciated the necessity of exactness in tenotomy and improved the instruments and technique accordingly. Among the first to show the importance of latent deviations, and laid the foundation, in America, of the rational treatment of such defects. Died Nov. 12, 1900.

LANDOLT, EDMUND. Born in Aarau, Switzerland, 1846. Studied at Zürich under Horner. Worked with Aubert in the study of torsion, especially torsion with convergence. In 1874 opened his clinic in Paris. 1879, published part of the *Traité complète d'ophtalmologie*; in 1886, *The Refraction and Accommodation of the Eye*. Wrote on operations on the muscles in the second edition of *Graefe-Saemisch*.